Middle School Science

PHYSICS

Classes 7 & 8

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Middle School Science

PHYSICS

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Preface

This text book has been written as a preparatory course, to provide a strong foundation in Physics to the middle school students. Our effort is to provide sufficient knowledge and an appreciation of everyday phenomenon for an intelligent appreciation of modern progress in Physics.

In offering this text to teachers and students the following considerations have been kept in mind.

(a) Theory should be sufficiently interspersed with practical activity in the development of a topic. Many experiments and demonstrations have therefore been suggested so that students may be guided to form concepts based on observation and interpretation of experiments.

(b) Lengthy explanations and unnecessary mathematical derivations should be avoided in a first-acquaintance presentation to science. Problems, both theoretical and numerical, have therefore been included with an aim to show further applications of the principles rather than to engage students in repetitive work.

(c) A number of clear illustrative diagrams should be included to help students in proper assimilation of the subject matter.

The material has been successfully trial-tested for several years by the authors and their colleagues. However the authors realise that there is no unique way to teach a subject. Critical comments and suggestions from teachers who actually use the book in their classroom are therefore welcome.

January 1985

B G Pitre
I B Kakar

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1

Physics—An Experimental Science

We usually divide the course of science into various subjects, such as Physics, Chemistry and Biology, but it should always be remembered that this division is only for our convenience for a proper study of the subjects. In order to study in greater details and for specialisation even Physics branches off into topics such as electricity, spectroscopy, nuclear physics, heat, magnetism, etc.

Physics is primarily concerned with the study of matter and energy, and the means by which one form of energy may be changed into another.

1.1 The Importance of Physics

For the past three hundred years or more, the study of Physics has been taken up seriously by scientists; this has led to the inventions of radio and T.V., rockets and satellites, fans, refrigerators and a host of appliances we use at home. Thus, material progress is largely due to the efforts of physicists and engineers.

Man has come a long way from the days when he lived in caves, wore animal skin and ate raw meat. We have only to look around ourselves to know how science has influenced our lives. This book you are reading requires ink, paper and letter-types which were made in factories and reached the printing press from far away distances. Printing a single book requires a team of scientists and engineers trained in their tasks. They have been trained to operate machines, they realise the importance of team work. They are prepared to face unexpected breakdowns. They have acquired those qualities of thought and action essential for progress and prosperity.

Through this systematic course in the study of Physics, you are being initiated and prepared for a career in science and technology. How far you progress will largely depend upon how well you train yourself. This is a training in the scientific method.

1.2 The Method of Physics

Research and development in science follows a definite pattern. Some problems are met; the urge to explore and understand leads the scientist to make observations and perform experiments to gather information about the problem. Scientists often use simple pieces of apparatus such as a thermometer, microscope, etc. to gain better and more accurate information. Sometimes expensive gadgets such as computers are also used.

With the aid of mathematics, the physicist discovers a pattern in the observations. This leads to an explanation of the problem. Let us try this method ourselves.

Experiment 1. Collect the following objects: a piece of rubber tubing, a stone, an eraser, plasticine, a steel spring, a rubber ball, a piece of wood, a balloon, a metal block, a rubber band. Take the objects one by one and see if you can change its shape by squeezing, stretching or twisting. Make a table of observations as below.

S. no.	*Name of object*	*Change of shape? (Yes/No)*	*Is change lasting (Yes/No)*
1	Rubber tubing	Yes	No
2	Stone	No	—
3	Plasticine	Yes	Yes
	....	...	...

You have collected some information through **experimentation and observation**; this has been recorded properly. The next step would be to group the objects under different heads; this is called **classification**.

The experiment shows that rubber band, steel spring, rubber tubing and balloon stretch very easily, and regain their original shape easily. They all form a set of elastic objects.

Such a discovery of the behaviour of some objects can be useful to us. Let us try another experiment to understand the usefulness of this property.

Experiment 2. Fig. 1.1 shows how the experiment can be set up. The steel spring S is hung up, and a pan attached at its lower end. A thin pointer P fixed at this lower end moves along a vertical ruler R. We place some known weights W in the pan and record readings of the pointer on the scale.

S. no.	*Weight* (in g wt.)	*Reading on scale* (in cm)
1	0	0
2	50	2.4
3	100	4.8
...	...	...

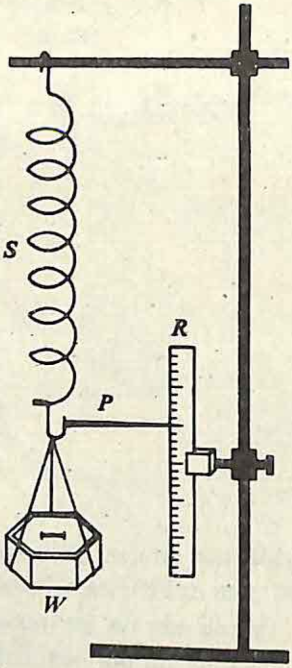


Fig. 1.1

You conclude that when the weights in the pan, i.e. the pull on the spring increases, the spring extends more.

You can also remove the weights and notice the reading of the pointer on the scale.

Now let us look at a practical application of this discovery. Place a stone on the pan and record the reading of the pointer on the scale. Can you guess the weight of the stone?

Thus, our **conclusion** from the experiment can be useful to find out unknown weight of objects. We have, in fact, constructed a simple model of a spring balance.

The challenges facing physicists have not come to an end; nor are they likely to get exhausted in the near future. Thousands of Indian physicists and engineers are occupying high positions, working all over the world. You may well be aware of names of some very outstanding physicists of India: Jagdish Chandra Bose, C.V. Raman, Homi Bhabha, Vikram Sarabhai.

1.3 How to Study Physics

This book answers some of the questions that physicists have asked in the past. The information is mixed with experiments which the scientists themselves carried out in order to arrive at the answers. Repeating these experiments will give you an understanding of the answers to several of your own questions on matter and its behaviour, energy and its transformation.

You should use this book for homework, to revise and to answer questions at the end of each chapter. This will make sure that you really have understood the topics of the chapter.

EXERCISES

1. What does each of the following scientist do? What is his special field of study?

an astronomer__________

a nuclear physicist__________

a geologist__________

a meteorologist__________

2. Gather information from books and magazines to answer the following questions.

(i) Will man ever stay permanently on the Moon? __________

(ii) Where is the National Physical Laboratory located in India? __________

(iii) Which are some of the discoveries or inventions made by its scientists? __________

2

Measurements—The Beginnings of Physics

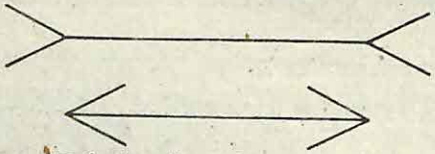
Many great discoveries in science have only been possible because of accurate measurements. Scientific experiments require the making of measurements. Measurements alone provide reliable information. Fig. 2.1 poses some questions. Reliable answer can be given only if we use a scale to measure the relevant lengths.

2.1 Standard Units of Measurement

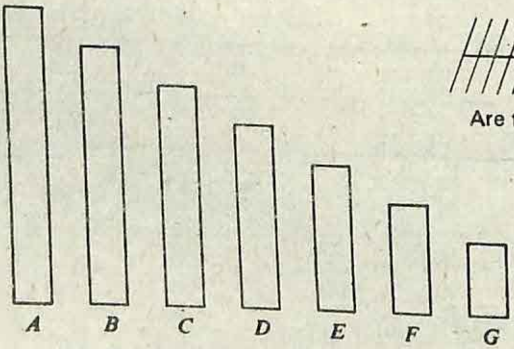
A quantity such as length which can be measured is called a **physical quantity**. The most important measurements are those of **length, mass** and **time**. These are done by comparing them with certain **standard units** accepted by all scientists.

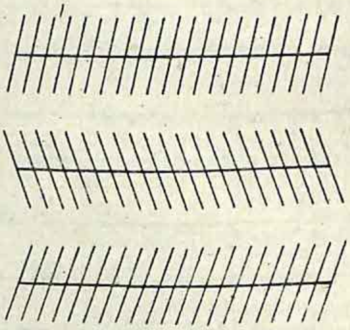
The standard unit of length (or distance) is the **metre**. For practical purposes other larger and smaller units are also used. These related units are as follows.

1 kilometre (km) = 1000 metres (m)
1 m = 100 centimetres (cm)
= 1000 millimetres (mm)

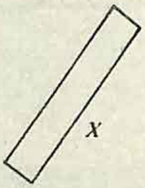


Are the two lines of equal length?





Are the long lines parallel?



In order of height will *X* go between *CD* or *DE*?

Fig. 2.1

A kilogram is the standard unit for measuring mass. Its multiple and sub-multiple units are as follows.

1 tonne = 1000 kilograms (kg)
1 kg = 1000 grams (g)
= 1000 × 1000 milligrams (mg)

Time is measured in **seconds**. The related units are:

1 hour = 60 minutes
1 minute = 60 seconds (s)

During an athletic meet, measurements of all kinds are made. Field judges measure distances using tapes, and track judges time races with watches. Athletes are weighed on balances for grading in different events.

Every measurement always contains two terms: a unit and a number. The number tells us how many times the physical quantity is bigger or smaller than the unit. For example, a shot put throw of 7.5 m indicates that the athlete threw it to a distance of $7\frac{1}{2}$ times the length of a metre scale. We can use the above table of length to change the unit from metre to centimetre as follows:

$$7.5 \text{ m} = 7.5 \times 100 \text{ cm} = 750 \text{ cm}$$

2.2 Measurement of Length

Suppose we want to find out the length of a pencil. We proceed as follows.

Experiment 1. Place the pencil along one edge of a **scale** so that one of its ends coincides with any whole division on the scale. Fig. 2.2 shows three positions of the eye to observe readings on the scale. The reading is faulty if viewed from positions *a* and *c*. The eye must be placed vertically above the scale mark (position *b*) to read correctly.

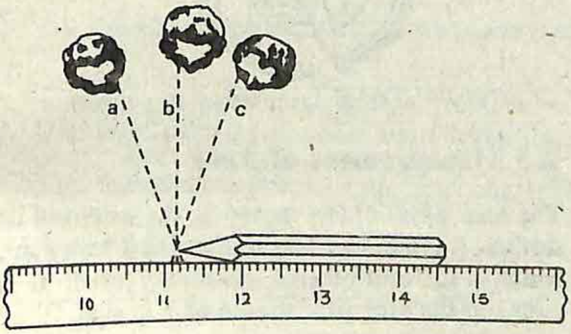


Fig. 2.2 Measurement of length with a scale

Many times the edges of the scale may be worn out. Hence, we take the correct reading at both ends; the difference of these two readings gives us the length of the pencil.

To measure the length of the pencil, the instrument we have used in the above experiment is the scale.

2.3 Measurement of Mass

Mass is the quantity of matter contained in an object. The unit we use for measurement of mass is the kilogram (kg). The instrument we use for measurement of mass is the **beam balance**. A physical balance available in the laboratory is shown in Fig. 2.3.

To begin weighing, we first adjust the levelling screws provided at the base of the balance so that the base is horizontal. In this position the plumbline is just above the pointed end of a knob fixed on the base. The beam is raised and made free to move by turning a lever. Balancing screws on both arms are provided which can be adjusted to ensure that the pointer swings equally on either side of the central zero mark on the scale.

Now lower the beam. Place the object to be weighed on the left pan. Using a pair of forceps, place known weights on the right pan so that when the beam is raised, the pointer swings equally on either side of the zero mark. The weight of the object is equal to the weights placed on the right pan.

Two following precautions should be noted.

(a) A hot or a wet object should not be placed on the pan.
(b) Weights should be placed on the pan only when the beam is lowered.

2.4 Measurement of Time

Unlike the units of length and mass, the unit of time cannot be stored; it must therefore repeat

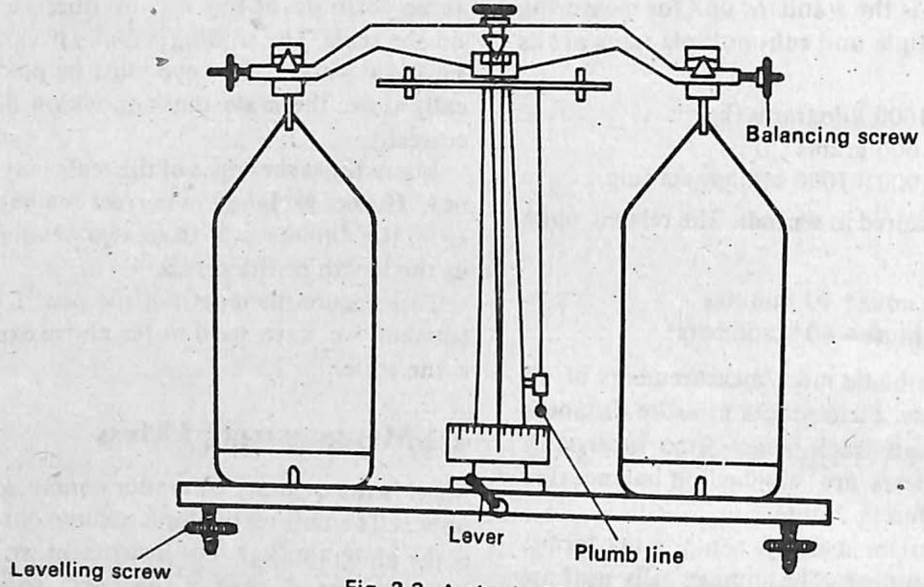


Fig. 2.3 A physical balance

itself. A system which repeats itself at regular intervals of time is called a **periodic system**. The measurement of time is really the comparison of an unknown time with a standard time interval of a periodic system.

Some natural repeating phenomena known to man from early times are the beating of the heart, day and night, and the seasons. But they vary and cannot be relied upon. The heart beats faster after an exercise, the sun does not rise at the same time every day, nor are the seasons reliable.

Sun dial, water and sand clocks were used in earlier ages for measurement of time intervals. But the real advancement in the measurement of time was made when clocks were invented. A clock has a **pendulum** which moves to and fro (**oscillates**) at regular intervals of time (Fig. 2.4a). The balance wheel of a watch serves the same function (Fig. 2.4b).

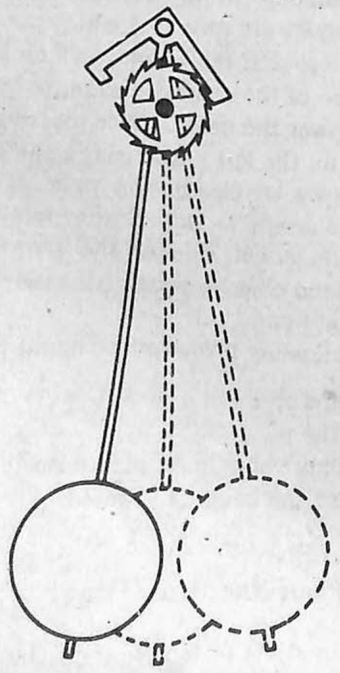


Fig. 2.4 (a) Pendulum mechanism in a clock

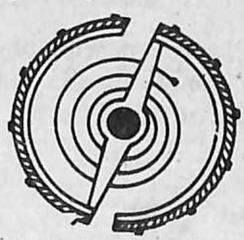


Fig. 2.4 (b) Balance wheel in a watch

2.5 Measurement of Area

The area of an object measures the extent of its surface. It is measured by comparing it with 1 m^2, which is the unit of area commonly used. It is equal to the area of a square of 1 m side.

$$1\ m^2 = 1\ m \times 1\ m$$

The smaller units of area are 1 cm^2 and 1 mm^2 and they are interrelated as follows.

$$\begin{aligned} 1\ m^2 &= 1\ m \times 1\ m \\ &= 100\ cm \times 100\ cm \\ &= 10{,}000\ cm^2 \\ 1\ cm^2 &= 1\ cm \times 1\ cm \\ &= 10\ mm \times 10\ mm \\ &= 100\ mm^2 \end{aligned}$$

The area of regular shaped bodies can be determined as follows.

Area of a square = side^2

Area of a rectangle = length × breadth

Area of a circle = $\pi \times \text{radius}^2$ $\left(\pi = \frac{22}{7}\right)$

Area of a regular or irregular shaped surface can be determined conveniently by using a centimetre graph paper (Fig. 2.5). Trace the boundary of the surface on the graph paper. Count the number of enclosed squares; more than half squares are counted as full while less than half are ignored. Since each square is equal to 1 cm^2, therefore the number of full and more than half enclosed squares gives the area of the surface.

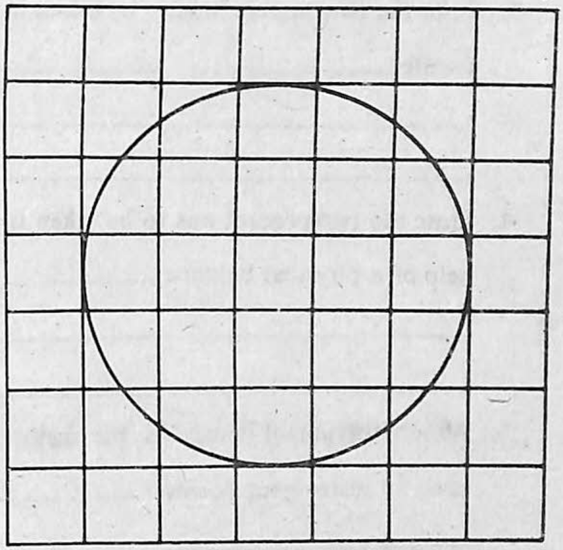


Fig. 2.5

Check the result by calculating the area of the circle used in Fig. 2.5 by measuring its radius and using the formula given above.

EXERCISES

1. Why are actual measurements necessary in science? ____________________

____

____

2. (i) Which are the three most important measurements? ____________________

____

(ii) Which are the standard units taken for these measurements? In each case give a relation between the standard unit and one of its multiple units. ____________________

____

____

____

3. State the two precautions to be taken in measuring the length of an object with the help of a scale.

4. State the two precautions to be taken in the measurement of the mass of an object with the help of a physical balance.

5. Which instrument is used in the measurement of time? What important property should such an instrument possess?

6. A brick is 25 cm long, 10 cm wide and 6 cm thick. What is

(i) the area of its largest surface?

(ii) the area of its smallest surface?

7. Tie the ends of a 20 cm thread together to form a closed loop. Now spread this thread on a squared paper to make following shapes:

(a) a square of side 5 cm

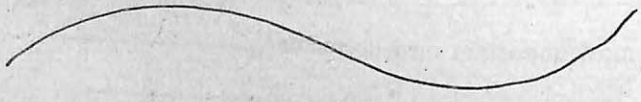
(b) a rectangle of length 6 cm

(c) a circle

Find the area of the loop in each case.

Which of these shapes gives the maximum area?

8. Find out the length of the irregular line shown below.



(Place a thin cotton thread along the line. Mark the two ends of the thread coinciding the two ends of the line. Now straighten the thread along a ruler and measure the length.)

3

Measurement of Volume and Density

The space which an object occupies is called its **volume**. Whether solid, liquid or gas, every matter has some volume. A shadow or an idea are not matter; they do not occupy space, nor do they have any mass.

3.1 Volume of Liquids

A liquid does not have a fixed shape. It has to be stored in a container. When the vessel or container is filled with a liquid, the volume of the liquid equals the inner volume of the vessel. The full (maximum) volume that a container can hold is called its **capacity**.

The volume of liquids is measured in **litres (l)**. The sub-multiple millilitre (ml) is commonly used in measurements.

1 litre = 1000 ml or 1000 cm^3

You may have noticed metal cans being used at petrol stations to measure engine oil. Kerosene is also measured in measuring cans. The capacity of each can is recorded on the can.

In the science laboratory volume of liquids is measured by many different types of containers, some of which are shown in Fig. 3.1.

Experiment 1. By pouring out the liquid from a bottle or any container into a measuring jar, it is possible to find out the volume of the liquid as well as the capacity of the bottle. Carry out this experiment to find out the capacity of some containers, such as a beaker, a medicine bottle and a tea cup.

3.2 Volume of Solids

A solid has more or less a fixed shape. It is not easy to change this shape, nor can its volume be changed easily. Some solids have a regular shape; a cone, a ball, a cube and a rectangular

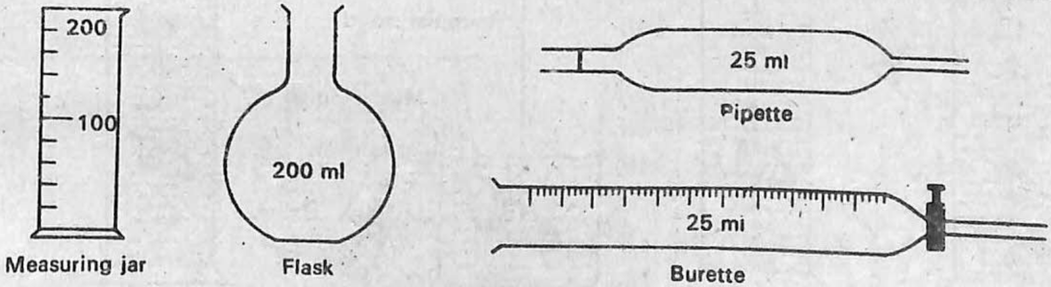


Fig. 3.1 Containers used for measuring the volume of a liquid

block of a metal are some examples of regular solids. The volume of such solids can be calculated from their geometrical measurements.

Volume of a cube = (length of a side)^3
Volume of a rectangular block
= length × breadth × thickness

A glass stopper, a stone or an iron bolt are irregular solids. How can the volume of such an object be found out?

The volume of an irregular solid is found out by the method of **displacement**. The method consists of finding out the volume of a liquid, say water, that the solid displaces.

Experiment 2. Pour water in a measuring jar and note the reading of the water level. This gives the volume of water contained in the jar. Now tie the irregular solid to a string and lower it gently into the water so that the solid is completely immersed (Fig. 3.2b).

The water level will show a rise equivalent to the volume of the solid. Record the new level of water. The difference in the two readings will give you the volume of the solid.

Experiment 3. Another method of finding out the volume of an irregular solid is by using a **displacement** or **overflow can**. Fill the can completely till water overflows through the side tube. Now hold a measuring jar under the side tube and slowly lower the solid in the water till the solid is completely immersed (Fig. 3.2c). The solid will displace water equivalent to its own volume; this water is collected in the measuring jar and its volume determined.

If a solid floats on water, for example a cork piece, its volume cannot be determined by the above displacement method. In such a case, a massive lump called a **sinker** is used.

Experiment 4. Pour water in a measuring jar. Tie the sinker to a thread and lower the sinker in water till it is completely immersed. Note the reading. Now tie the cork piece and the sinker together and lower them in water till both are completely immersed; note the reading on the jar again (Fig. 3.2d). The second reading is more than the first one by a quantity equal to the volume of the cork piece. In this experiment it is essential that the water is not spilled over when the sinker is raised up for tying the cork.

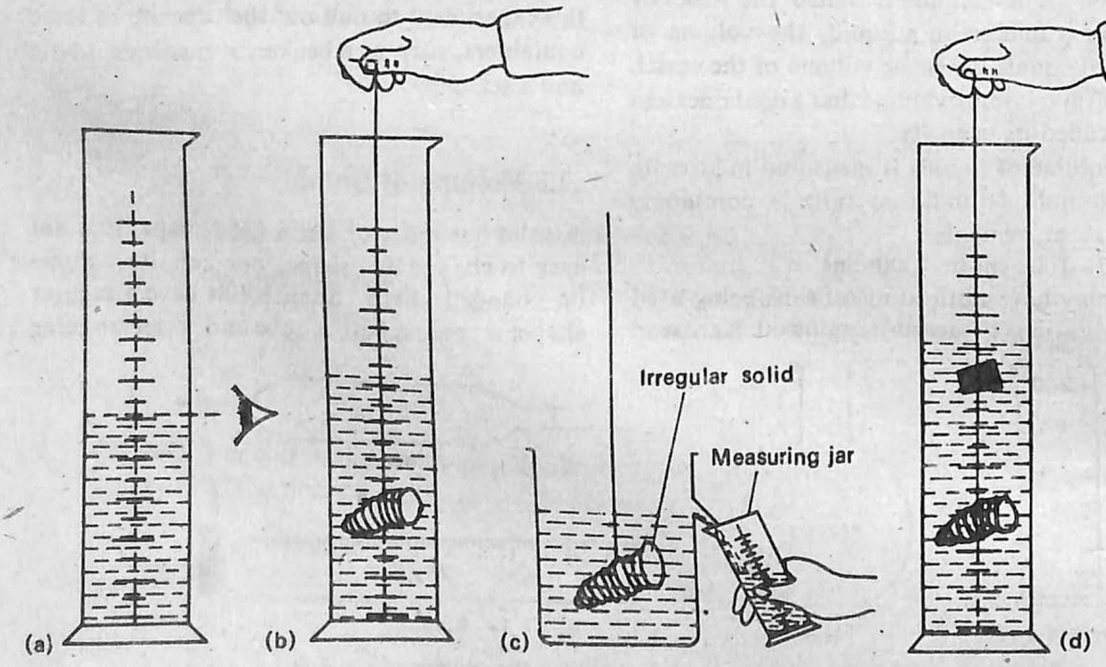


Fig. 3.2 Measurement of volume of an irregular solid by displacement of water

3.3 Density

Is wood heavier than iron? Many of us would say 'no'. But a wooden desk is heavier than an iron nail. Which is heavier, a lump of lead or a bag full of feathers? Actually 1 kg of lead weighs exactly the same as 1 kg of feathers; both have the same quantity of matter contained in them. What, then, is the difference? To understand this, we must study another important property of matter known as density.

If 1 kg of lead and 1 kg of feathers are taken you will notice that their volumes are different. And, if the same volume of iron and wood are taken, you will notice that their masses are different. *The mass of a unit volume of a material is known as its* **density.**

$$\text{Density (g/cm}^3\text{ or g/ml)} = \frac{\text{Mass of the object (g)}}{\text{Volume of the object (cm}^3\text{ or ml)}}$$

3.4 Density of Solids

The mass of an object can be found out by weighing it on a beam balance. Its volume can be determined by displacement methods or geometrical measurements. Hence, density can be calculated.

Experiment 5. Take three rectangular blocks of aluminium of different sizes. Measure the side of each block. Hence, calculate the volume. Also, find the mass with a beam balance. Record your observations in Table 3.1.

Table 3.1

Block	*Length* (cm)	*Breadth* (cm)	*Thickness* (cm)	*Mass* (g)	*Volume* (cm^3)	*Density* (g/cm^3)
A						
B						
C						

You will notice from the results that although the mass and volume of the blocks are all different, the density is the same. Thus, density of the material has a fixed value.

Experiment 6. Now take rectangular blocks of different materials—iron, lead and wood. Find out the density of each material by a similar experiment. You will notice that even if they all have equal volume, the mass is different; hence, density of the materials is different.

3.5 Density of Liquids

Unlike solids, liquids have to be carried and kept in containers. Hence, the mass of a liquid is found out by **difference-measurement.**

Experiment 7. Weigh an empty beaker on a physical balance. Fill it about two-thirds with a liquid and weigh again. The difference between these two weights gives us the weight of the liquid. Now pour the liquid in a measuring jar and record the volume. Hence, calculate the density, the ratio of mass to volume of the liquid.

Take water, kerosene oil, mercury and find out their densities.

Table 3.2 gives the densities of some common materials.

Table 3.2

Material	*Density* (g/cm^3)
Wood	0.6-0.7
Ice	0.9-0.92
Aluminium	2.6-2.7
Iron	7.8-8.1
Lead	11.3-11.4
Kerosene oil	0.79-0.81
Water	1.0
Mercury	13.5-13.6

3.6 Relative Density

The density of iron is about 8 g/cm^3 while that of aluminium is 2.7 g/cm^3. How many times is iron denser than aluminium? **Relative density (R.D.)** is the ratio of density of one material to the density of another material. For example, the relative density of iron is 3 in comparison to aluminium. Such an information is helpful in deciding which material should be used in a particular technology, such as construction of aircrafts, girders for bridges, etc.

It is customary, however, to mention relative densities in relation to water as the standard material. Taking the case of iron, its relative density with that of water would be 8. The R.D. of mercury is 13.5. What would be the R.D. of aluminium?

Expressed mathematically,
Relative density of a material

$$= \frac{\text{Density of the material}}{\text{Density of water}}$$

It is important to note that the density of a material in different units will have different numerical values; however, the R.D., as a ratio of two densities expressed in the same units, will have no units.

3.7 The Density Bottle

The density bottle is a specially designed bottle that allows us to find the R.D. of liquids and powders fairly accurately. The essential feature of the bottle is that it has a glass stopper, which fits accurately into the neck of the bottle, and has a hole through its middle to allow excess liquid to overflow(Fig. 3.3). This allows the bottle to be filled to the very top. Hence, the capacity of the bottle remains the same no matter which liquid is inside it.

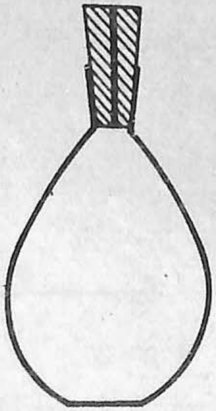


Fig. 3.3 The density bottle

Experiment 8. Weigh a clean, dry and empty bottle along with the stopper. Fill it fully with a liquid. Gently tap it to drive away any air bubbles, and push the stopper into the neck. Wipe off excess liquid that overflows, and reweigh the bottle. Similarly, weigh water in the bottle taking care that the bottle is cleaned and dried properly before water is poured. The observations can be recorded systematically as follows:

Mass of empty bottle $= x$ grams (say)
Mass of bottle + liquid $= y$ grams (say)
Hence, mass of liquid which fills the bottle $= (y-x)$ grams
Mass of bottle + water $= z$ grams (say)
Hence, mass of water which fills the bottle $= (z-x)$ grams
Hence, R.D. of liquid

$$= \frac{\text{Mass of liquid}}{\text{Mass of equal volume of water}}$$

$$= \frac{y-x}{z-x}$$

3.8 Density of Air

A difficulty about finding the density of gases is that they weigh very little, so that we are required to take a large amount of gas to weigh them on ordinary balances. There is also another real difficulty.

Experiment 9. Take a bicycle pump and put your thumb over the hole so that no air can come out when you push the piston down. Push the piston down and then release it. What do you notice? Squeeze a hollow rubber ball and then leave it. Does it remain squashed? Pump a lot of air into a bicycle tube and see how the tyre holds the air you squeeze into it.

From these simple experiments on air you will realise that a gas can be compressed rather easily like a spring. This poses a problem of finding out its density. The density would be quite different for air if it is squashed (like air in a bicycle tube) than for the air you breathe. Would the air inside the bicycle tube have a greater or lesser density than the air outside?

Experiment 10. Take a large polythene or tin container, like those used for storing petrol or oil, and attach a tap to it. Weigh the container on a large beam balance. Now pump a lot of air into the container again; its mass should increase by about 6 grams. This increase in mass gives the amount of air pumped into the container from outside.

Now release the compressed air under water in a trough so that bubbles of air rise and are displaced in a jar which was initially full of water (Fig. 3.4). When all the water is displaced, take the jar out, fill it with water again and place over the trough. Repeat the process till you get as many jars filled with air as you can. When the capacity of one jar is known, the total volume of air which came out can be found out. The mass of this air has already been determined. Hence, its density can be calculated.

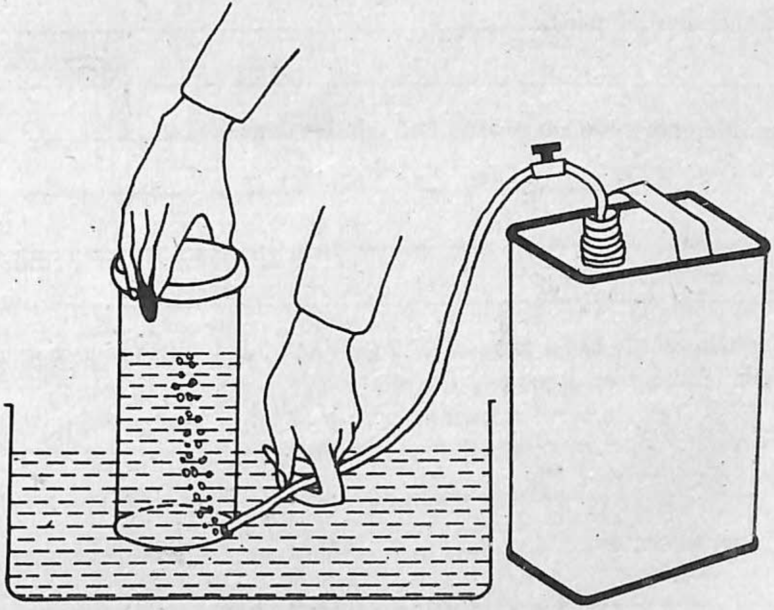


Fig. 3.4 Determination of density of air

EXERCISES

1. Define the following.

(i) Mass ____________________

(ii) Volume ____________________

(iii) Density ____________________

Which of these quantities is constant for aluminium? ____________________

2. By calculation, complete the following table.

S. no.	*Mass* (g)	*Volume* (cm^3)	*Density* (g/cm^3)
1	100		2.5
2	210	20	
3		25	8.9

3. A window pane is 1 metre square and 3 mm thick. If the density of glass is 2.5 g/cm^3, find the mass of the window pane. ____________________

____

4. Explain the difference between density and relative density. ____________________

____

____

____

5. An empty density bottle has a mass of 20.2 g. When filled with water it weighs 45.2 g; and 40.2 g when filled with kerosene oil. Calculate

(a) Capacity of the bottle ____________________

____

(b) Relative density of oil ____________________

____

6. State whether the following statements are true or false.

(i) The volume of a solid that floats in water cannot be determined by the displacement method.

(ii) 1 kg of lead weighs more than 1 kg of wood.

(iii) The density of a solid does not depend on its size or shape.

(iv) If a solid is heated its density decreases.

(v) The air inside a car tube will have the same density as the air around us.

4

Motion, Force and Energy

The use of force in our daily life is just as common as breathing. We freely make use of forces to kick a football, to lift a glass of water, to walk on the ground, to catch or throw a cricket ball, to ride a bicycle, to open a door, etc. It is in fact impossible to live without applying force. There are many different types of forces but most of them can easily be put under two sets : **push** and **pull**. If you want to move a lawn mower you either push or pull it.

4.1 Push and Pull

Experiment 1. Push a ball along a floor and it starts rolling (Fig. 4.1a). Hold your hand firmly in the path of a rolling ball and it will stop (Fig. 4.1b). Actually, in this case you apply a force in the opposite direction to its motion. Now hold your hand firmly at an angle to a moving ball in its path. You will notice that the direction of the moving ball changes (Fig. 4.1c).

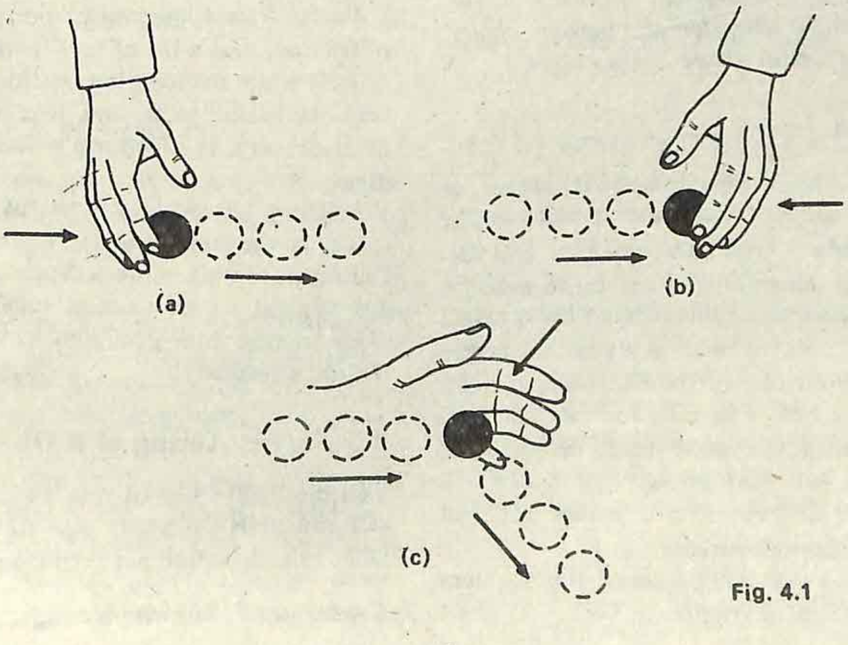


Fig. 4.1

All these actions are often employed while playing cricket ; to stop or catch a ball, or while driving a ball with a bat.

Experiment 2. Hold a spring in your hand and pull it; it extends in length. Push the spring from both ends and it gets compressed in length. Hold an eraser in your hand and twist it; the eraser gets deformed in shape.

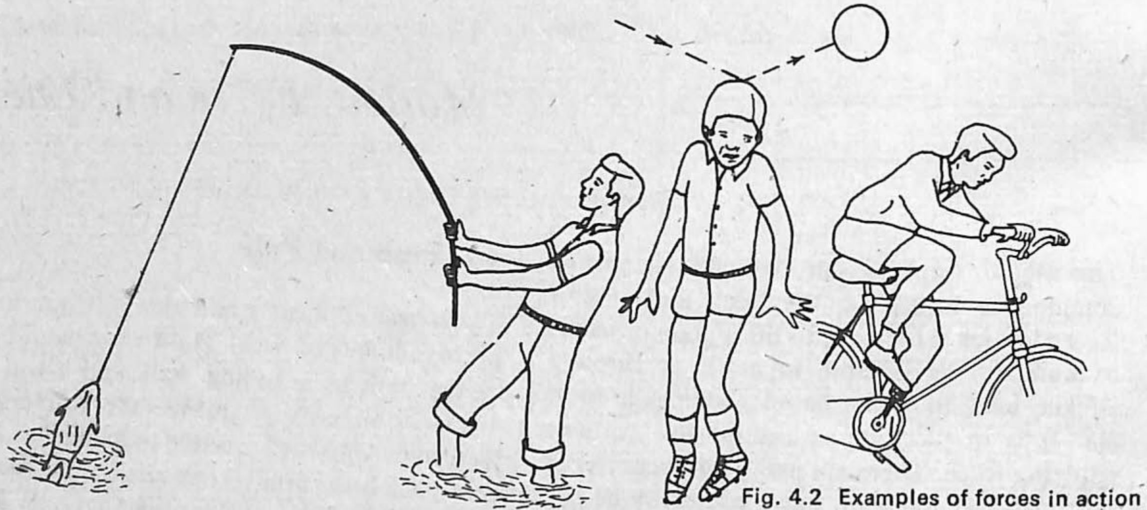


Fig. 4.2 Examples of forces in action

We observe that the push or pull may have several different effects : *a force moves an object from rest or makes an object move faster or slower or changes the direction of a moving object, or changes the size or shape of the object.*

4.2 Friction

If you push a ball, it rolls forward. However, it gradually slows down and comes to rest even if you do not stop it. The ball comes to rest because an opposing force is developed between the surface and the rolling ball. This is called **friction.** If the ball is rolled on a smooth surface such as the floor of your house, it will travel a longer distance before coming to rest than if it were rolled with the same force on the lawn outside. You will also notice that a new ball with a smooth surface will roll further than an old ball with a rough surface.

This indicates that roughness of the surfaces increases the force of friction.

It is also a common experience that an empty box can be moved more easily than one which is full of clothes, even if the floor is the same. These common experiences show that :

(a) when an object moves over another, there exists a force which opposes the motion. This is called the force of friction.

(b) friction increases with roughness of the two surfaces in contact.

(c) friction increases with weight of the object when surfaces are the same.

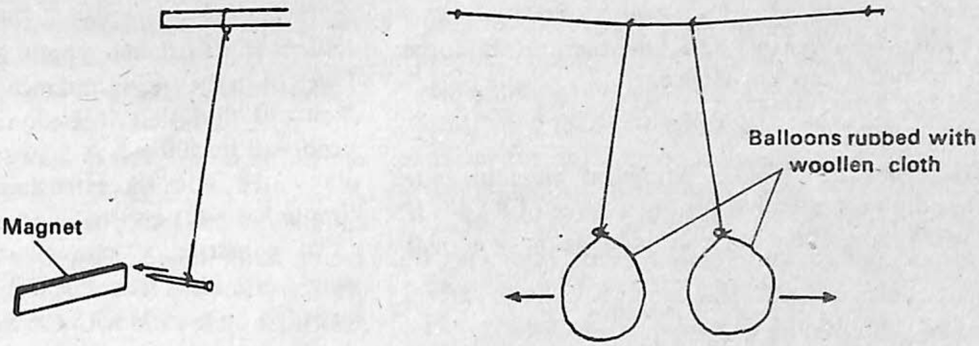
Parts of machinery wear out easily because of friction, and a lot of fuel is wasted in driving objects while overcoming friction. The force of friction, hence wear and tear in moving parts of machinery, is effectively reduced by applying grease or oil on them.

Friction however is a useful force in other cases. It prevents vehicles from skidding and enables us to walk without slipping. When brakes are applied to stop cars, bicycles, etc. they cause friction to be produced which opposes the motion effectively.

4.3 Forces Acting at a Distance

You must have played with magnets and observed how nails and paper pins stick to a magnet. Does this attraction act even from a distance ?

Experiment 3. Suspend a nail from a stand with



(a) Magnetic force

(b) Electrostatic force

Fig. 4.3 Forces acting at a distance

the help of a piece of thread. Now gradually bring a magnet close to it (Fig. 4.3a). You will notice that the nail gets pulled towards the magnet even when the two are not in contact. The **magnetic force** of the magnet acts from a distance.

Suspend two inflated balloons by long pieces of thread from the roof or an overhead beam so that the two balloons are at the same level and are separated by about 10-15 cm. Now rub both the balloons against a woollen cloth and again release them carefully (Fig. 4.3b). You will notice that they push each other away. The force between the balloons is known as the **electrostatic force.** You will read about it in higher classes.

4.4 The Force of Gravity

The most familiar of all forces acting at a distance is the force of gravity. It is the force with which the Earth pulls an object towards itself.

Experiment 4. Hold your hand stretched horizontally and ask someone to place a brick on your open palm. Do you feel the force of gravity on the brick pushing your hand downwards ?

Everyone on the Earth, and every object that we see, experiences the force of gravity. It is such an important force which we always have to reckon with that we give it a special name: **weight.** *The weight of an object is the force by which the Earth pulls it towards itself.* This force therefore always acts downwards.

The weight of an object is not the same at every place on and around the Earth. Just as in the case of magnets and balloons in an earlier experiment, this force becomes weak with increase of distance as the object is removed away from the Earth. When we lift a brick, we apply a force upwards against the pull of gravity. When a magnet lifts a nail from the ground, its magnetic pull is more effective than the downward pull of gravity.

On the Moon the pull on an object is due to the Moon. The Moon is much smaller than the Earth; any scientific instrument or an astronaut, will therefore weigh much less on the Moon than on the Earth.

4.5 Measurement of a Force

A small force may not produce any visible change but a large enough force often produces an effect that we can notice. A small wind force may cause mere rustling of leaves; a large force may cause movement of branches. The force of wind during a storm may even uproot trees. When you sit on a bench, it may hardly show any visible change; perhaps a creaking sound may be heard. If the load on the bench becomes too large, it may even break. Bridges have been broken by the force of river waters during floods.

Forces are measured in comparison with standard forces. *The force with which the Earth* *pulls a mass of 1 kg towards itself is called* **1 kilogram-force** or **1 kg-f**. One-tenth of this force is named 1 newton. Hence,

1 kg-f = 10 N

Experiment 5. Hold a kilogram mass in your hand. You are now feeling a force of 1 kg-f. If you keep a 100 g mass on your palm, you will feel a force which is very nearly equal to 1 newton. If you hold a 1 g mass in your hand, you will feel a very tiny force which is called 1 g-f or 1 gram-force.

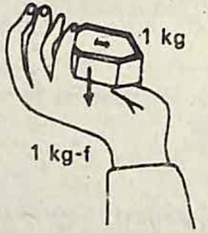


Fig. 4.4 A mass of 1 kg produces a downward force of 1 kg-f.

One of the simple instruments used to measure forces is the **spring balance**.

Experiment 6. Hang a spring from a hook and measure its length. Now attach a weight of 500 g-f to its free end. You will notice that the weight produces an extension in the spring. Measure the increased length of the spring and find out the extension produced by the weight of 500 g-f. On removing the weight you will find that the spring returns to its original length. Now attach a 1 kg-f weight to the spring and measure the extension. You will find that it is double the extension produced by 500 g-f. A 1.5 kg-f weight will produce three times the extension. This serves as a simple basis for constructing a spring balance.

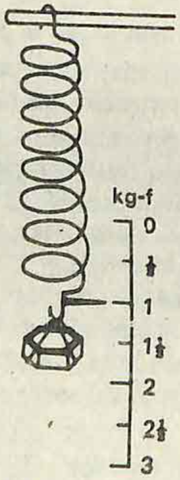


Fig. 4.5 A spring balance

To construct a spring balance, standard weights are hung from a spring and the extension recorded on a scale with the help of a pointer. The scale is thus **calibrated**; an unknown load can be measured by hanging it from the spring and reading the force shown by the pointer.

4.6 Energy

After a hard game or a long swim, one often hears the comment: 'Oh, I am finished! I have no energy left.' Most people feel like this at the end of the day after having done a good day's work. The energy they had in the morning has been spent during the day. A hearty meal and you hear: 'Ah! I am full of energy again.' What does food do?

Food enables us not only to breathe and think but also allows us to do things like running, carrying books to school or playing a game of football. Just as a motor car needs fuel to run, so do our bodies need fuel which is supplied in the form of food. Fuel supplies energy to the car and makes it run. Food supplies us with energy to enable us to carry out various activities.

4.7 Forms of Energy

We see that all useful jobs require energy for the job to be done, and this energy is supplied by fuel. We say that energy in fuels is stored in the form of chemical energy. The same sort of thing happens in a cell which is used to light a torch, or in coal required to run a steam engine.

What happens to the stored chemical energy when a cell needs replacement, or once coal has turned into ash? Does it simply disappear? As a matter of fact, the light and heat that we get from these are also forms of energy because these can be used to do useful jobs.

So instead of the chemical energy simply disappearing, it has changed its form.

When you wind a clock, you transfer some of your energy to store energy in the spring of the clock. Energy stored in springs is known as **strain energy** or **elastic energy.**

The stretched rubber band of a catapult (Fig. 4.6) can throw a pebble with great speed. An arrow shot from a bow utilises the strain energy which we give to the bow when we stretch the string.

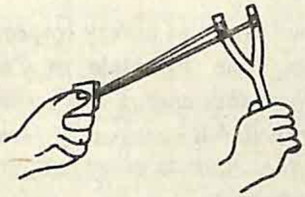


Fig. 4.6 A catapult converts strain energy to kinetic energy

The arrow or the pebble in the above examples gain energy when they are made to move with some speed. Anything that is moving has motion energy; in scientific language it has **kinetic energy.**

Running water of a turbulent stream can wash away a bridge; it can also be put to use to turn a turbine to produce electrical energy. Similarly, blowing wind can uproot trees and cause much damage; its kinetic energy can also move the vanes of a wind mill.

A raised load can do a job while going down. Greater the height from the ground, more is the job that the load can do. Hence we say that a raised load has energy due to its raised position. The scientific name for this energy possessed by an object due to its raised position is **gravitational potential energy.** If the name sounds too long, you could call it simply potential energy. The pull of the Earth (gravity) is responsible for it.

4.8 Energy Transformations

Can you think of some other forms of energy? The idea that energy changes from one form to another when jobs are done, is a very important idea in science. However, what name we give to a particular form of energy, or whether it is different in any way from energy in some other case, is a matter of discussion. We give special names for the sake of convenience, so that we can remember these special cases.

Other forms of energy are **electrical energy, light energy, heat energy** and **nuclear energy.** Heat received from the Sun dries up ponds, and changes water from the seas into clouds. These clouds carried by the winds form the monsoon rains over most of India. Light energy from the Sun helps plants to grow. When you think of huge amounts of energy, you may think of hydrogen or atomic bombs; in these explosions (Fig. 4.7) nuclear energy from some elements is utilised to give heat, light, etc.

Experiment 7. Hammer a piece of lead or any thin piece of metal a few times. Touch the metal

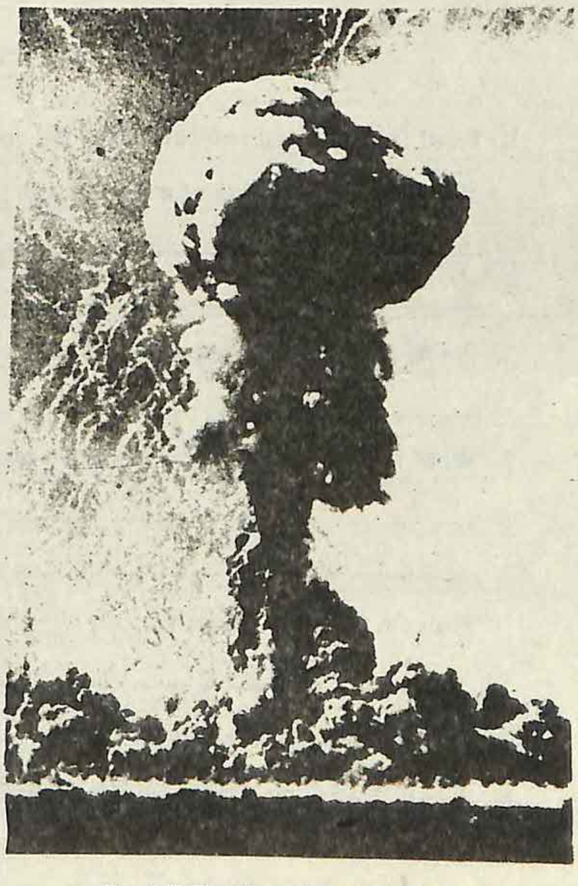


Fig. 4.7 The blast of an atomic bomb

and you will find that it has become warm. The energy changes are as follows:

Chemical energy	→	Potential energy	→	Kinetic energy	→	Heat energy
(of food in in our body)		(in hammer when we raise it)		(in hammer during fall)		(in metal)

Thus energy is transferred from one kind to another in a sequence.

Experiment 8: Support from a stand a metal bob attached to a string. Displace it to one side and release it. It starts swinging to and fro.

At the extreme ends it comes to rest momentarily before moving in the reverse direction. In these extreme positions, the bob possesses no kinetic energy but maximum potential energy. At the mean (middle) position the bob possesses maximum kinetic energy.

Thus, there is an interchange from potential to kinetic energy, and vice versa, as the bob vibrates. This can be written as

$$\text{Potential energy} \rightleftharpoons \text{Kinetic energy}$$

In actual practice some energy gradually gets wasted due to friction with air and at the point of suspension. Hence, the bob gradually comes to a stop.

Thus, we arrive at a very important principle in Physics. The **Principle of Conservation of Energy** *states that energy can neither be created nor destroyed, but changes its form from one to another; the sum total of all energy always remains constant.*

EXERCISES

1. What is the unit of measurement of a force?

   Name the three effects of a force.

2. Name two special types of forces which act from a distance.

3. What is the difference between mass and weight?

   How do these quantities vary for an object on Earth when it is taken to the Moon?

4 When a ball is rolling on the ground what type of energy does it possess?

When the ball gradually slows down due to the force of friction, what happens to the energy?

5. When an object is lifted up against the force of gravity, what changes occur in its

(i) weight?

(ii) energy?

6. State the energy changes in the following examples.

(a) A swinging pendulum.

(b) A speeding car is brought to rest by the application of brakes.

(c) A bicycle gathering speed on being pedalled.

(d) A toy car is wound up and allowed to run upward on an inclined table.

(e) A Diwali rocket is fired upwards from the ground.

7. State two ways in which friction is

(i) useful

(ii) harmful

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8. State the principle of conservation of energy.

9. Fill in the blanks.

(i) Most forces can be classified as ____________ or ____________.

(ii) Increase in surface roughness ____________ (increases/decreases) friction.

(iii) An object weighs 10 kg-wt. In outer space, where there is no gravity, its weight will be ____________.

(iv) The energy a body possesses due to its motion is called ____________ energy.

5

Pressure

The word pressure is in common use. Scientists, however, give it a definite meaning. Let us take an everyday example. People living in top storyes of buildings often complain that they do not get enough water from the taps. Some buildings have pumps fitted to them which lift water up to a high level; the water is raised up to create the required **pressure** at the taps. When a lot of air is squeezed into a balloon, the **pressure** inside has been increased in comparison to that outside. As soon as an opening is created by the prick of a pin, the air at high pressure rushes out. Thus, difference of air pressure is the cause for its movement.

Most of you have seen gas cylinders being used in houses. Why does gas come out of them when the tap is opened? When a cylinder supplies no more gas, we say it is empty. In this condition, is there no gas at all inside? In cooking gas cylinders, almost 15 kg of gas is compressed initially. When the tap is opened, excess pressure inside causes the gas to flow out freely. As the gas is used up, this difference in pressure gradually becomes less. When no more gas comes out, a 'pressure balance' between outside and inside is achieved.

You are well aware that tyres have to be 'inflated' with air. Those who own a scooter or car may have noticed that the excess pressure in a tyre is measured by a meter called a **pressure gauge**. When you have a flat tyre, the meter reads zero; this means that the pressure of air inside is the same as that outside.

5.1 Liquid Manometer

Experiment 1. Take a 3 metre long polythene tubing and fix it vertically in the form of a U-tube; pour water from one end so that the water level is about 50 cm above the base (Fig. 5.1a). You will notice that the horizontal level of water in both limbs is the same. Now blow through one end as hard as you can. Note the change of water level, and the difference d in the two levels (Fig. 5.1b).

The difference in level d is an indication of your 'lung' pressure; it shows how much pressure your lungs can build up in excess of outside air pressure. Repeat the experiment blowing through the other end, and you will realise that water is pushed down in that limb but the difference in levels remains unchanged.

Experiment 2. There are two other variations of this experiment which you should try. Connect one end of the tube to the laboratory gas tap. The water column in the limb joined to the supply will be pushed down (Fig. 5.2a). The water column p will indicate the excess gas pres-

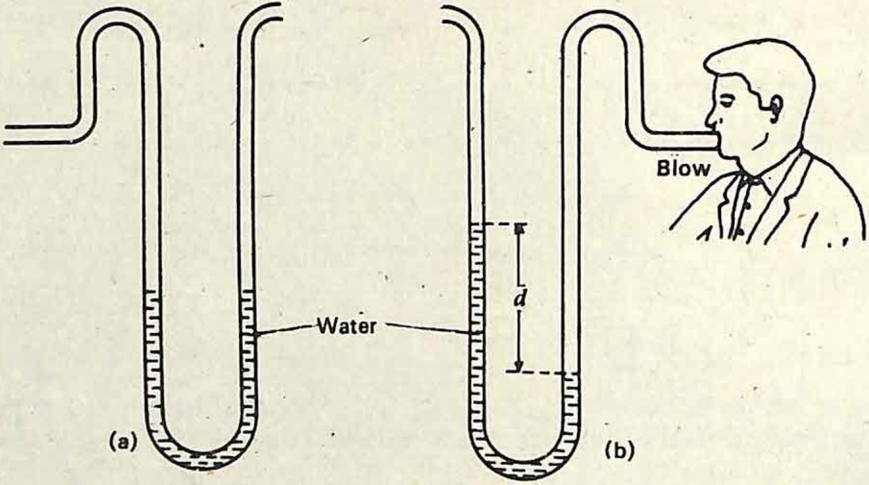


Fig. 5.1 Measuring 'lung' pressure with a liquid manometer

sure. You can compare the gas tap pressure with your 'lung' pressure.

Now replace water in the tubing with a liquid of low density such as kerosene or turpentine oil. Connect one limb to the gas tap again and note the liquid column supported by the excess pressure. You will notice that the difference in liquid levels is not the same now (Fig. 5.2b). *A less dense liquid will require a greater column to achieve a pressure balance.*

Next set up a similar U-tube using two polythene tubings of different diameters joined near the base (Fig. 5.2c); the initial level of water in the two limbs remains equal. Now connect one end of the tube to the gas tap, and then the other end. You will observe that the liquid column supported by the excess pressure is the same either way; *the different diameters of the two limbs containing different quantities of the liquid do not matter.*

This U-tube liquid apparatus, which indicates difference of pressures acting on the liquid surfaces in the two limbs, is called a **manometer.** To compare small differences in pressure, a liquid of low density is used because it creates a greater column of the liquid; thus, sensitivity of the

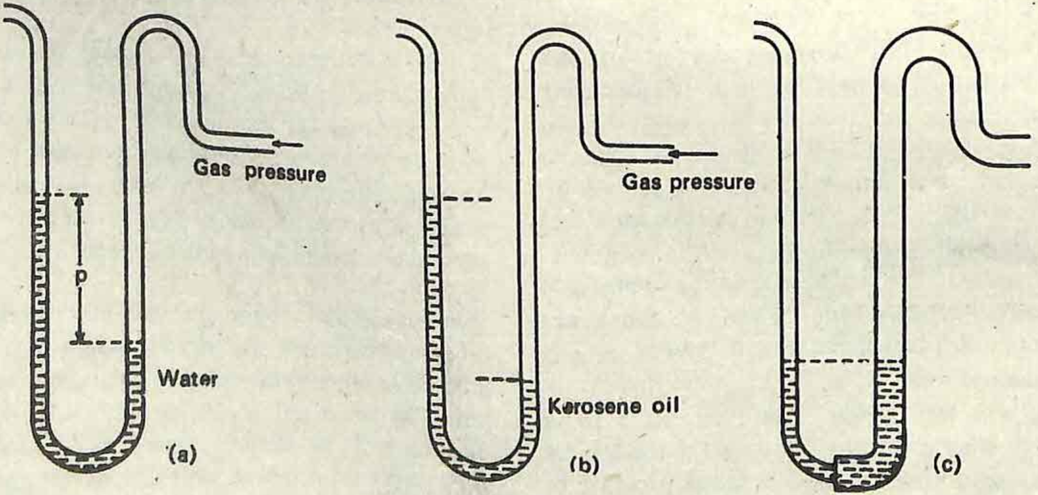


Fig. 5.2

instrument is increased. It may be noted that the diameter of the limbs is of no consequence, except that a wider tube will require more liquid.

5.2 Liquid Pressure

Experiment 3. Take a wide glass tube open at both ends and tie a thin rubber membrane at its lower end. Pour some water in the tube and you will notice that the membrane bulges downwards (Fig. 5.3a). This shows that liquids exert pressure on the base of a vessel in which they are contained.

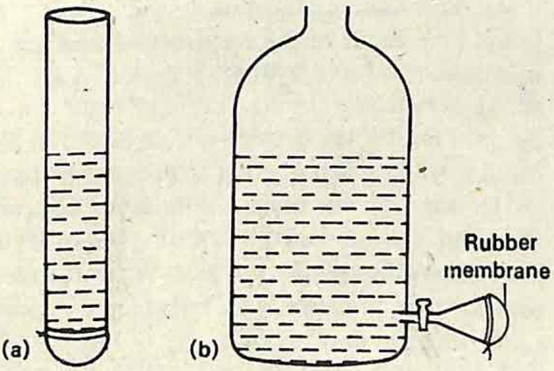


Fig. 5.3 Liquids exert pressure in all directions

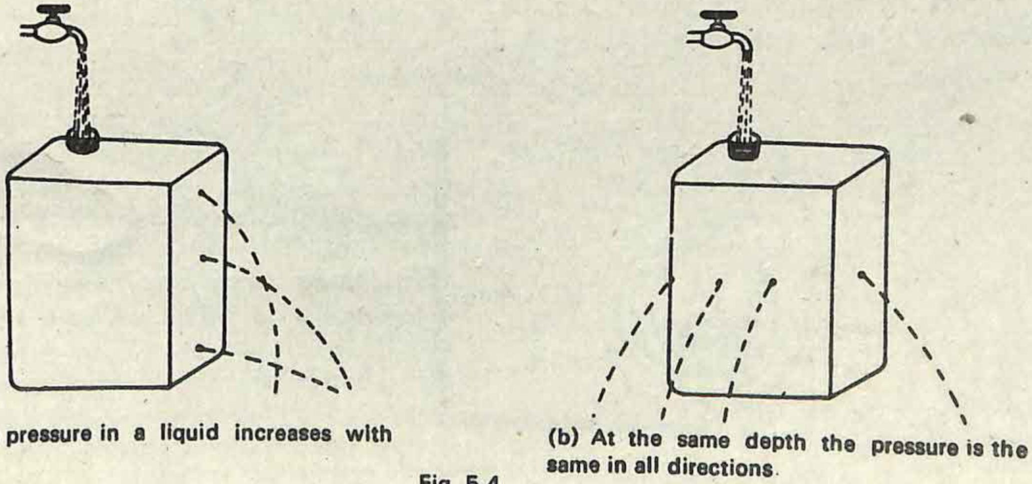
Experiment 4. Take a bottle which has an opening from the side just above the base. Use a tight-fit cork to fix a funnel into the opening and cover the mouth of the funnel with a thin rubber membrane. Now pour water in the bottle and you will notice that the membrane bulges outward, showing that it is being pressed from inside (Fig. 5.3b).

The experiments show that liquids exert pressure not only on the base of a container in which they are kept but also on the walls of the container. This existence of sideways pressure is one of the differences in the behaviour of solids and liquids.

Experiment 5. Take a polythene container and make a few holes in it at different levels. Hold it under a tap of running water to fill it fully and then adjust the opening of the tap so that water maintains its level. You will observe that the pressure with which water flows out increases according to the depth of the hole under the water surface (Fig. 5.4a). *The pressure in a liquid increases with depth.*

The fact that pressure in a liquid increases with depth finds extensive applications. Deep sea divers wear a stout steel suit to withstand the high pressure which acts on them at great depths. Submarines are built with hard steel of good thickness to withstand the high pressures under water.

Now make some more holes in level with one of the existing holes and as before maintain the water level in the container. You will notice that the water flows out of the holes at the same level with equal pressure (Fig. 5.4b). *Thus, at the*



(a) The pressure in a liquid increases with depth

(b) At the same depth the pressure is the same in all directions

Fig. 5.4

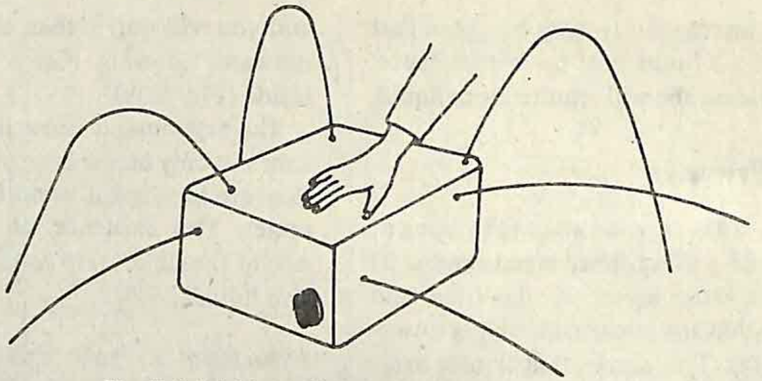


Fig. 5.4 (c) Transmission of pressure in a liquid

same depth the pressure is the same in all directions. The thickness of a dam is made broader at the base so that it can stand the high pressure acting sideways as depth of water increases.

5.3 Transmission of Liquid Pressure

Experiment 6. Make some holes on various faces of the polythene container. Fill the container completely with water and close its mouth with the cap. Press it hard with your hand; you will notice that water spurts out in all directions (Fig. 5.4c). The water comes out with equal pressure through all the holes.

The result of this experiment can be summed up in the form of a law. *When pressure is applied to an enclosed fluid, it is transmitted equally to all parts of the fluid.* This is called **Pascal's principle**. The principle is applicable to gases as well.

An important application of transmission of liquid pressure is in the construction and use of hydraulic press and hydraulic brakes. Fig. 5.5 shows how the hydraulic brakes of a car work. By stepping on the brake pedal, a piston in the master cylinder is pushed. The pressure is transmitted through the brake oil pushing the brake shoe and lining against the rotating brake drum. This brings the vehicle to a halt. When the pressure on the brake pedal is released, the spring pulls back the shoe.

5.4 Force and Pressure

Do you know why camels can walk without much difficulty in sandy deserts? What would happen if nails had sharp points at both ends?

Experiment 7. Hold a thumb tack between your two fingers and press it as hard as you can. You

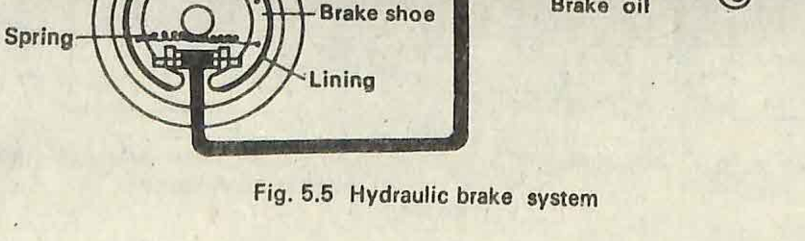


Fig. 5.5 Hydraulic brake system

will fell it painful at the sharp end and there will be a deep mark due to it. It is very painful to carry a heavy parcel holding it with a thin string; hold the same load with a thick string and you feel much relieved.

Place a brick on soft plasticine or fine sand and it will create an impression on the surface. Two bricks, one on top of the other, will make a deeper impression. Now spread the bricks on a wider surface and the impression is shallow. You will realise that the depth of impression is different due to different pressures acting on the surface. Greater load (or greater force) increases the pressure while a larger surface area decreases the pressure.

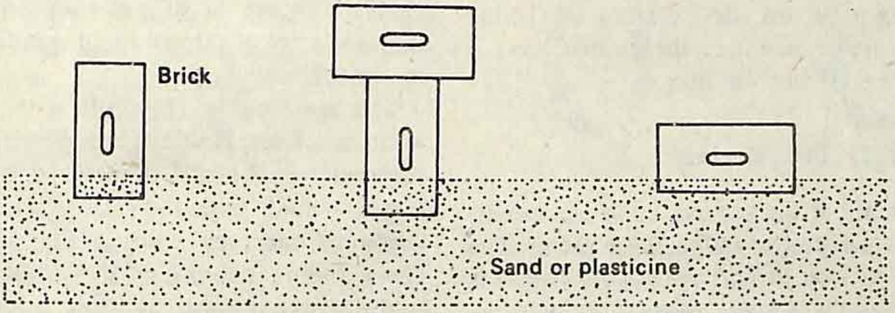


Fig. 5.6 Pressure depends on force and area

The three quantities force, pressure and area are related in a simple way which can be expressed mathematically as follows:

$$\underset{(\text{N/m}^2 \text{ or g-f/cm}^2)}{\text{Pressure}} = \frac{\text{Force (N or g-f)}}{\text{Area (m}^2 \text{ or cm}^2)}$$

This explains why flat-footed camels can walk easily in sandy deserts. Heavy tractors can go through marshy land and muddy soil easily because their rear wheels have large area. The caterpiller tracks of tanks and huge excavators helps them to negotiate any uneven and sinking ground because the pressure exerted on the ground is comparatively less. On the other hand, cutting and piercing tools like saws, needles and knives have sharp points or blades so that they exert great pressure with comparatively small applied force.

5.5 Atmospheric Pressure

The air envelope surrounding the Earth is called the atmosphere. It is comparatively dense near the Earth's surface, and becomes rarer at high altitudes. The pressure of atmosphere is due to the weight of the air column acting on a specified area at any place. Due to transmission of fluid pressure, at any point this pressure acts equally in all directions.

Experiment 8. Press a rubber sucker (Fig. 5.7) against a window pane till it becomes almost flat. Now try to pull it out. You will find that it is very difficult to pull it out because of the atmospheric pressure pushing it against the window pane. Because of the expelled air, there is no opposing force present to reduce the pressure difference.

The atmospheric pressure decreases at high altitudes because the air column above these places is short and rare. Jet planes nowadays

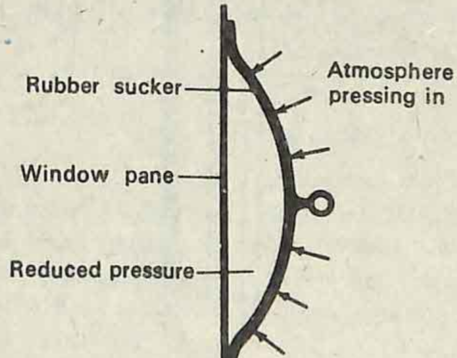


Fig. 5.7 Rubber sucker

fly at an altitude of about 10,000 metres; there is so little air there that these planes are all 'pressurised' so that we can withstand the low pressure and also breathe normally. Our body is not suited to conditions of very low and very high pressures. Space travellers in space ships and those who landed on the Moon could come out of their vehicles only when they were wearing space suits which were 'pressurised' from inside.

Change of atmospheric pressure at a place causes wind movements. Meteorologists, who forecast weather, keep track of wind movements by gathering data on air pressure and other weather factors of a region; the information is plotted on special weather maps.

5.6 Mercury Barometer

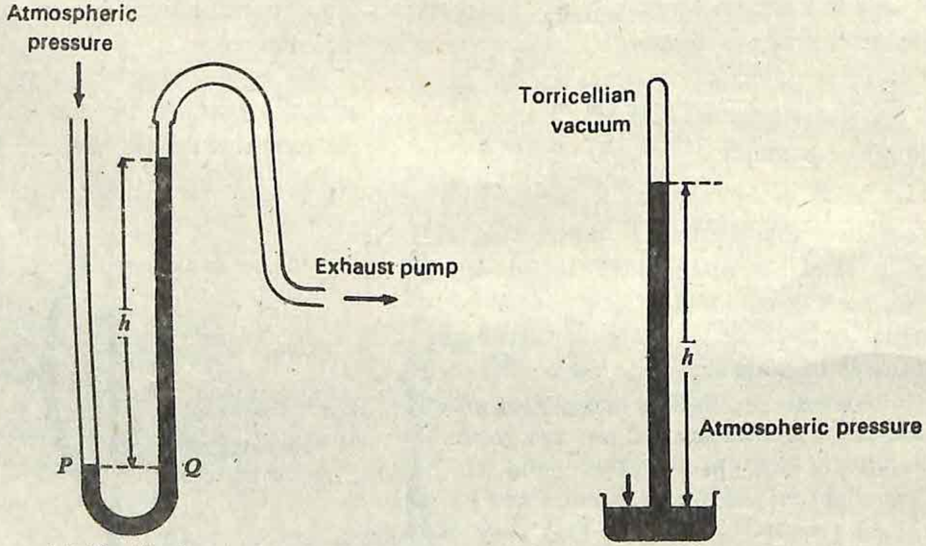
The air pressure at a place can be found out by reading an instrument called **barometer**. The U-tube can be used to find out the atmospheric pressure at a place in terms of mercury column.

Experiment 9. Take a 1 metre tall U-tube and fill it about half with mercury. Now connect one end to an exhaust pump. When all the air from this limb is taken out, mercury rises to 'balance' the atmospheric pressure (Fig. 5.8a). The pressure at the level P due to the atmosphere is equal to the pressure acting on common level Q, which is entirely due to h cm of mercury column. At sea level under normal conditions the mercury column is 76 cm.

Experiment 10. A different method, but employing no costly apparatus, to set up a **simple barometer** is as follows. Take a 1 metre long, narrow bore and stout glass tube closed at one end, and fill it completely with mercury. The tube should be tapped to ensure that there are no air bubbles inside. Now close the top end with a finger, carefully invert the tube so that the open end is inside a bowl of mercury and gradually release the finger.

The mercury in tube falls down slightly and settles to a level. Hold the tube vertical; the difference between the level of mercury in the tube and in the trough gives the atmospheric pressure in terms of mercury column (Fig. 5.8b). Atmospheric pressure acting on the surface of mercury in the bowl supports the h cm column of mercury in the tube. Above this column of mercury is vacuum which is called **Torricellian vacuum**.

It is advantageous to use mercury as a barometric material because it (a) is dense, so that a short column is necessary; (b) is silver in colour, so that it can be seen easily; (c) does not stick to glass, so that accurate reading can be



(a) The U-tube

(b) The simple barometer

Fig. 5.8

taken; and (d) forms very little vapour, so that the vacuum is almost true and the reading is accurate.

5.7 Aneroid Barometer

Mercury barometers are bulky and quite inconvenient to carry around. The most common type of barometer is the **aneroid barometer**, so called because it contains no liquid. Essentially, it consists of a box *B* which is partially evacuated (Fig. 5.9). The top of this box is made of a thin metal so that it is sensitive to small changes in pressure. This small movement of the top of the box is 'magnified' by a series of levers and causes the pointer to move along a circular scale. The scale is graduated with a good mercury barometer. The scale is usually marked stormy, fair, etc. because change of atmospheric pressure causes such changes in the weather.

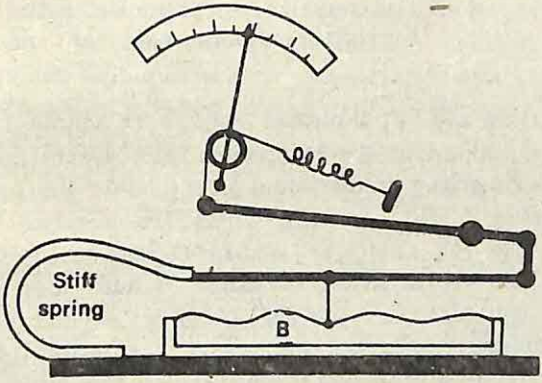


Fig. 5.9 Aneroid barometer

Aneroid barometers are also used as altimeters in aircrafts because increase of altitude is accompanied by decrease of atmospheric pressure; a fresh calibration of the scale is therefore sufficient to convert the instrument into an altimeter.

5.8 R.D. of Liquids by U-tube

Pressure in liquids is actually due to weight of liquid column acting on a specified area. This explains why unequal pressures acting on a liquid in two limbs of a U-tube create unequal levels. Consider a U-tube containing mercury. When both limbs are open to the atmosphere, pressures are equal on its two surfaces and the two levels are equal.

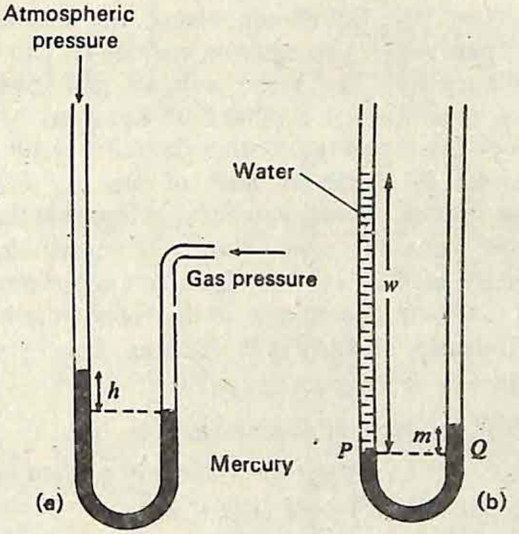


Fig. 5.10 R.D. of liquid by U-tube

Let us connect one end to the gas tap which creates a difference h in the two levels (Fig. 5.10a). We say that the gas tap pressure is h cm in excess of atmospheric pressure. If mercury has density d g/cm^3 and area of cross-section of the tube is A cm^2, then

Volume of h cm column of mercury

$$= A \times h \text{ cm}^3$$

Hence, mass of h cm column of mercury

$$= A \times h \times d \text{ gram}$$

and weight of h cm column of mercury

$$= A \times h \times d \text{ g-f}$$

Hence, pressure due to h cm column of

$$\text{mercury} = \frac{A \times h \times d \text{ (g-f)}}{A \text{ (cm}^2\text{)}}$$

$$= h \times d \text{ g-f/cm}^2$$

If the gas pressure increases, the height of mercury column will also show a rise. If a liquid of lesser density is used instead, the liquid column will have to be more. Both these deductions have already been experimentally verified by us earlier. This method also enables us to determine the R.D. of a liquid such as mercury especially if it does not mix with water.

Experiment 11. Pour some mercury in a U-tube. Next pour water through one limb till the limb is almost full. The water column will push down the mercury in that limb and there will be a resultant rise in the other limb (Fig. 5.10b). Consider the common level of mercury *PQ*. From earlier experiments it is obvious that the pressure due to water column *w* cm on the mercury surface at *P* is equal to the pressure due to mercury column *m* on the common level *Q*. If density of water is *W* and that of mercury is taken as *M*, in g/cm³ units,

then, pressure of water column *w*
= pressure of mercury column *m*

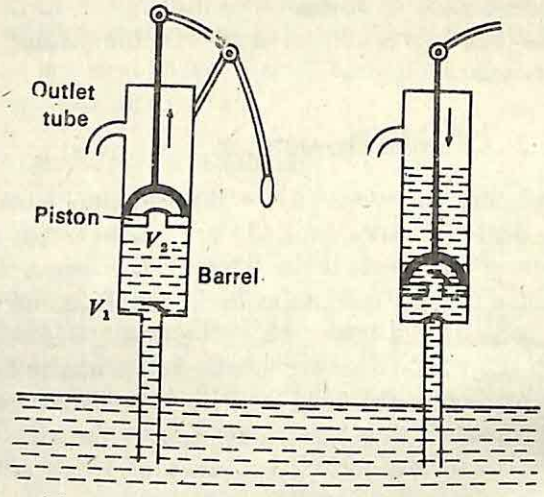
or $w \times W$(g-f cm²) = $m \times M$ (g-f/cm²)

Hence, R.D. of mercury (in relation to water)

$$=\frac{M}{W}=\frac{w}{m}$$

5.9 The Lift Pump

This mechanical device is used to raise liquids to higher levels. It consists of a cylinder (barrel) with a tight-fit piston and a handle; the bottom of the cylinder ends in a long tube which is immersed in the liquid. The two valves V_1 and V_2 open upwards. In the upward stroke of the piston, a partial vacuum is created inside the barrel; hence V_2 is closed by greater pressure from top. V_1 is pushed open as air, followed by liquid, enters the barrel due to atmospheric pressure acting on the liquid level outside the tube (Fig. 5.11a).



(a) Upward stroke (b) Downward stroke

Fig. 5.11 The lift pump

In the downward stroke the pressure in the barrel is raised which pushes V_1 and closes it; the valve V_2 is pushed open when air and then liquid comes out on top of the piston (Fig. 5.11b). In the next upward stroke the air and liquid come out of the outlet tube while the previous process in the barrel is repeated.

A lift pump is used where water is to be raised upto a height of about 10 m, which is the column of water the normal atmosphere can support.

5.10 The Exhaust or Suction Pump

The exhaust pump is similar in construction to the lift pump. It consists of a cylinder fitted with an air-tight piston and handle. The valve V_2 which opens outwards is fitted to the piston while valve V_1 is fitted where the cylinder is

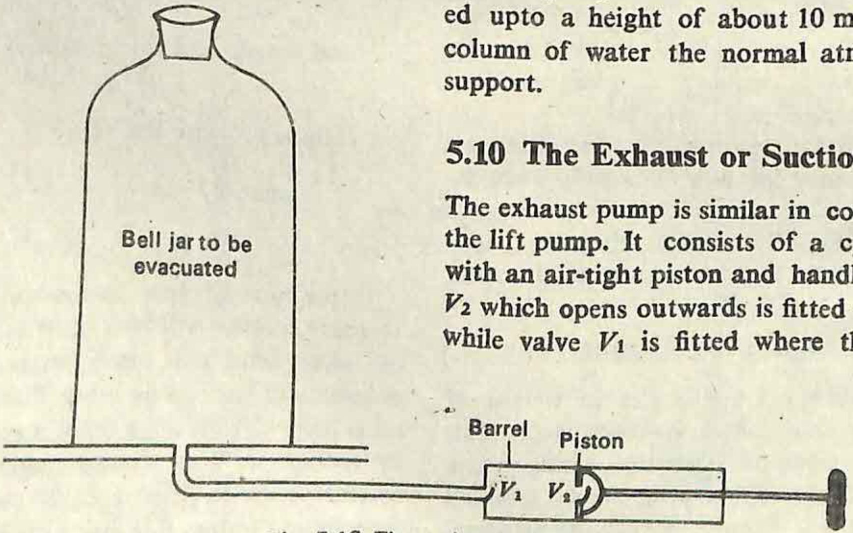


Fig. 5.12 The exhaust pump

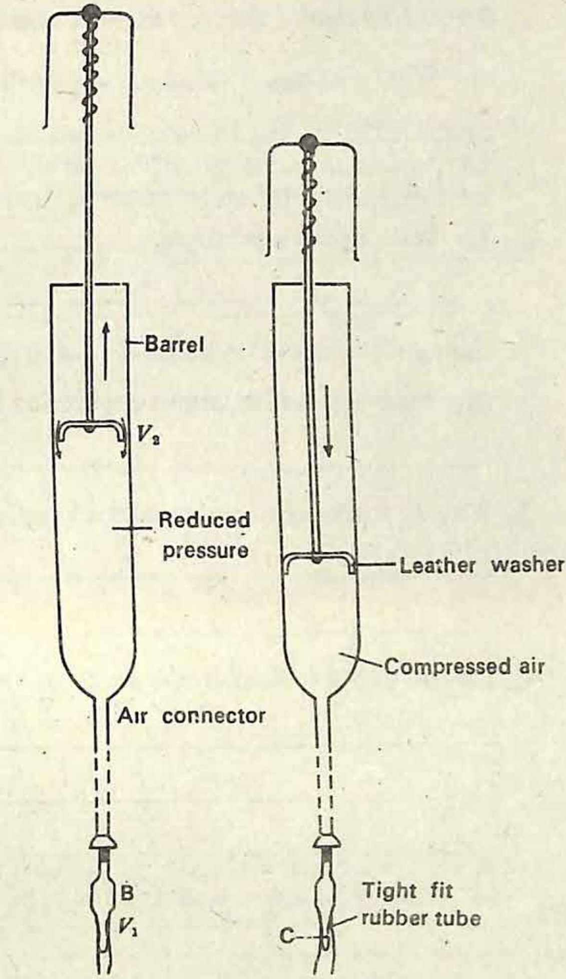
joined to the tube; the tube connects to a metal plate over which is placed the chamber, such as a bell jar, to be evacuated (Fig. 5.12).

During an outward stroke of the piston, partial vaccum is created in the barrel which closes valve V_2 and opens valve V_1 when air from the bell jar enters the barrel. In the downward stroke of the piston the air in the barrel is compressed which closes V_1; valve V_2 is pushed open when the air goes out. This process is repeated at each successive stroke.

It is necessary to remember that the bell jar can be evacuated only to the extent the barrel can be evacuated; at each outward stroke the air in the barrel must have lower pressure created than that in the bell jar. Vacuum grease is applied at all places such as between piston and barrel, and between jar and plate, so that no air escapes inwards.

5.11 The Bicycle Pump

The bicycle pump is used to transfer air from the atmosphere into the tyre of a bicycle; its valves are therefore fitted to open inwards.. The pump actually contains only one valve V_2 fitted to the piston while the other valve V_1 is fitted on to the bicycle tube. Valve V_2 is a cup-shaped leather washer while V_1 is a small piece of rubber tube which fits tightly on a metal tube B having a hole C (Fig. 5.13a).



(a) Upward stroke (b) Downward stroke

Fig. 5.13 The bicycle pump

When the piston is raised the opening C is closed; thus, no air from the tyre enters the barrel which has reduced pressure. Air from the atmosphere forces the leather washer to bend inwards and air enters the barrel. When the piston is lowered, pressure of air inside the barrel is raised. This presses the sides of the washer tightly against the walls of the barrel and closes it (Fig. 5.13b). The compressed air opens the valve tube V_1 and air enters the tyre.

EXERCISES

1. (i) One end of a manometer is connected to a gas cylinder. There is no difference in the liquid levels in the two tubes. What is the gas pressure?____________________

(ii) Which liquid will you use in a manometer to measure very large pressure differences? Why?

2. (i) State Pascal's principle.

(ii) Mention one important application of this principle.

3. Why do trucks and heavy vehicles have four wheels at the rear?

4. Explain why a footballer uses studs on his boots.

5. (i) What precautions would you take in setting up a simple barometer?

(ii) What difference, if any, would there be if you take a tube of greater diameter?

6. (i) Why is water not a suitable liquid for use in a barometer?

(ii) Which properties of mercury make it more suitable for use in a barometer?

7. The, R.D. of mercury is 13.6. What column of water would a 5 cm column of mercury support in a U-tube?____________________

____

8. A metal block 20 cm by 15 cm by 10 cm is kept on a table. The block weights 24 kg-f. How should it be placed so that it exerts least pressure on the table? What will the pressure be?

____

____

9. (i) Draw diagrams to show the upward stroke and the downward stroke in a lift pump?

(ii) To what maximum height can (a) water (b) mercury be raised with the help of such a pump? Why?____________________

____

____

____

10. State whether the following statements are true or false.

(i) Difference of pressure causes movement of a fluid.

(ii) A denser liquid in a manometer requires a greater column to achieve a pressure balance.

(iii) The pressure in a liquid does not change with depth.

(iv) Pressure increases as force increases.

(v) Atmospheric pressure decreases with height.

(vi) At sea level, under normal conditions the atmospheric pressure can support a mercury column of height 10 m.

(vii) Pressure is force per unit area.

6

Simple Machines

A **machine** is a device which enables us to do a job more easily. Riding a bicycle, pulling out water from a well, pushing a scooter up an incline into a verandah, taking a screw out from a wall bracket with the help of a screw driver, are examples where we use simple machines. In fact, a tractor or a factory workshop are examples of complicated machines in use in which a number of simpler machines work in combination. The simple machines most commonly used are: **pulley, lever, gear, screw,** and **inclined plane.**

6.1 Effort and Load

In practice we apply a force at some point on a machine; this is called the **effort**. By application of this force, we do some work, i.e. spend some energy; this is called the **input energy**. By doing so, with the help of the machine, a force is applied at some other point, to get some job done. The work done is called **output energy or useful work done.** In order to do this useful work, the force overcome is called the **load.** For example:

1. A heavy load L (Fig. 6.1) is lifted by applying an effort E on a crow-bar. The crow-bar is the machine used here. The arrangement is so made that the effort E is much less in comparison to the load overcome. Here, the machine has been used to **multiply force.**

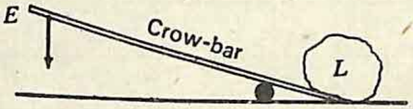


Fig. 6.1 A machine (crow-bar) can be used to multiply force

2. In hoisting a flag (Fig. 6.2) a pulley is fixed on top of the flag-post. The flag is raised up by pulling the rope down from the other end. The pulley is the machine used here over which the rope moves. The purpose of using this simple machine is to **change the direction of the force applied.**

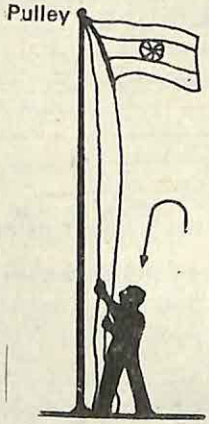


Fig. 6.2 A machine (pulley) can be used to change the direction of the force applied

3. When we apply force on the pedals of a bicycle (Fig. 6.3), this is transmitted by the chain to the rear wheel. By small movements of our legs, the wheels of the bicycle cover a greater distance. Thus, the machine has been used to **gain speed.**

Fig. 6.3 A machine (bicycle) can be used to gain speed

These are the three reasons for which we use a machine. Let us now consider these examples in some detail.

6.2 The Lever

The most common of all machines is the **lever.** In its simplest form a lever consists of a rigid bar supported at some point, called the **fulcrum** or **pivot,** about which the bar turns. The see-saw is a good example (Fig. 6.4). With this a small boy can even lift his heavier brother by increasing his distance from the fulcrum. His weight acts as the **effort** which lifts the greater **load** of his brother.

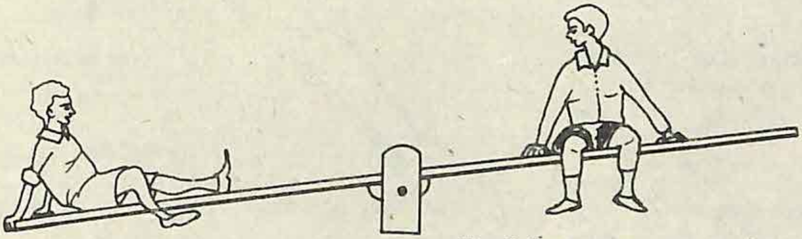


Fig. 6.4 A lever—the sea-saw

In the example, the lever acts as a force multiplier. The ratio of load overcome to the effort applied is called the **mechanical advantage.**

Mechanical advantage (M.A.)

$$= \frac{\text{Load overcome}(L)}{\text{Effort applied }(E)}$$

If the older brother weighs 40 kg and the younger brother weighs 25 kg.

$$\text{Mechanical advantage} = \frac{40 \text{ kg-f}}{25 \text{ kg-f}} = 1.6$$

The portion of the lever from the effort to the fulcrum is known as the **effort arm** and the portion from the load to the fulcrum is the **load arm.** It can be shown that

$$\text{M.A.} = \frac{\text{Effort arm}}{\text{Load arm}}$$

6.3 Single Fixed Pulley

Figure 6.5 shows a pulley mounted on a framework called a **block.** The pulley is a grooved wheel over which a rope passes. The wheel is able to rotate about an axle (which acts as the fulcrum) without moving as a whole. The load to be lifted is attached at one end while the effort is applied at the other end of the rope.

If the pulley is frictionless and the weight of the rope is ignored the effort to be applied in the pulley will be the same as the load.

$$\text{Effort} = \text{Load}$$

Hence $\quad \text{M.A.} = 1$

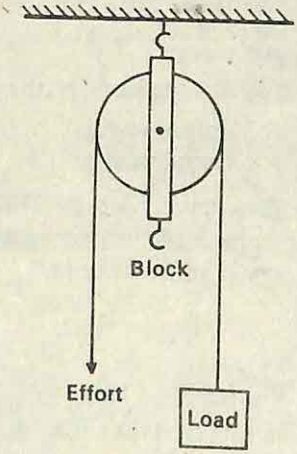
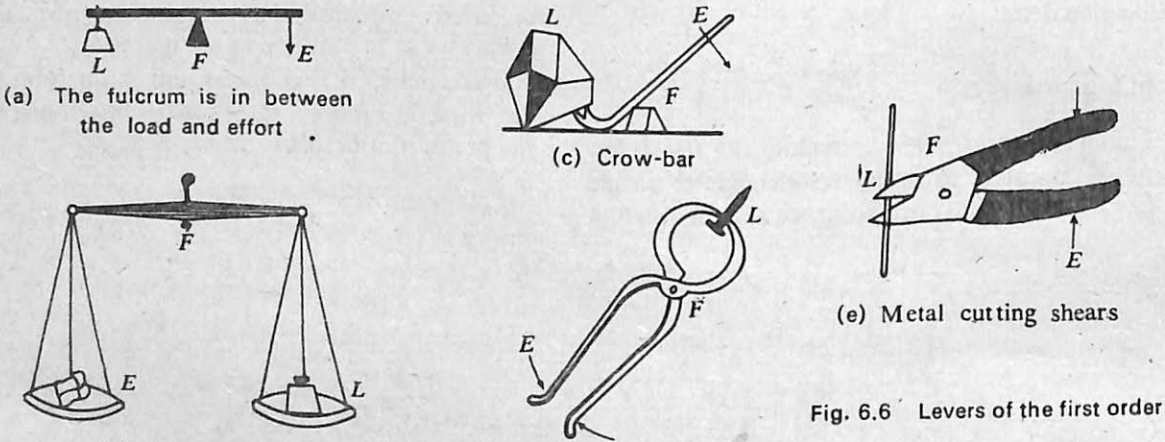


Fig. 6.5 A single fixed pulley can be used to change the direction of the force applied

Therefore, ideally a single fixed pulley gains neither in force nor in speed. It only changes the direction in which the force is applied. This is advantageous because pulling a rope downwards is invariably convenient than lifting a load upwards.

6.4 Efficiency

In practice there is always some friction between the axle and the block. Some extra energy is needed (which is a waste) to overcome the friction. Hence the useful work done (output energy) is always less than the input energy.



(a) The fulcrum is in between the load and effort

(b) Beam balance

(c) Crow-bar

(d) Pair of pincers

(e) Metal cutting shears

Fig. 6.6 Levers of the first order

$$\text{Output energy} < \text{Input energy}$$

or
$$\frac{\text{Output energy}}{\text{Input energy}} < 1$$

This ratio is called the **efficiency** of the machine.

$$\text{Efficiency} = \frac{\text{Output energy}}{\text{Input energy}}$$

In practice efficiency is always less than 1.

It must be emphasized that no machine can yield more energy than that put in.

6.5 Kinds of Levers

There are, in fact, three types of levers depending upon the position of the fulcrum, the effort and the load.

Lever of the First Order

In a lever of the first order, the fulcrum is in between the load and effort (Fig. 6.6a) as in the case of a beam balance and crow-bar.

Shears for cutting metal sheets (Fig. 6.6e) have long handles and short blades to obtain a greater mechanical advantage. Paper shears have short handles and long blades, so that the cutting is quicker; such shears gain speed by making a long cut with a short movement of the handles.

A lever of first order can have a mechanical advantage of

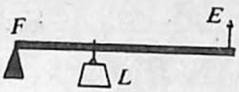
less than 1 (if effort arm < load arm);
equal to 1 (if effort arm = load arm);
greater than 1 (if effort arm > load arm)

Lever of Second Order

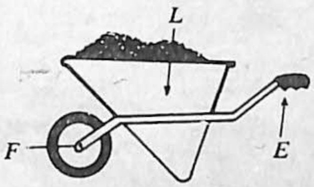
In this case, the fulcrum is at one end of the lever and the effort is applied near the other end. The load is in between the two (Fig. 6.7a). Examples are, wheel barrow, nut cracker, rowing of a boat, and a paper cutter. In this type of lever the effort arm is always bigger than the load arm, so that a greater load is overcome by applying a smaller effort. The mechanical advantage is always greater than 1.

Lever of Third Order

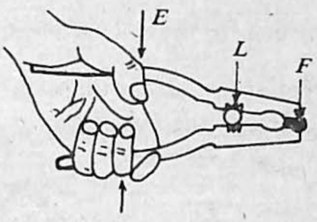
In this type of lever, the effort is applied in between the load overcome and the fulcrum (Fig. 6.8a). Examples are forceps, sugar tongs, safety valve, fishing rod and a spade used for



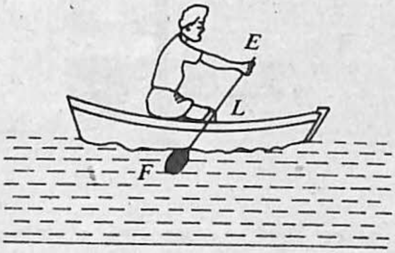
(a) The fulcrum is at one end, the effort is applied at the other end and the load is in between the two



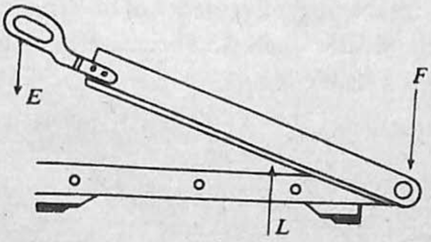
(b) Wheel barrow



(c) Nut cracker



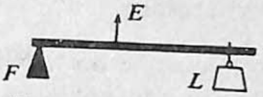
(d) Rowing of a boat



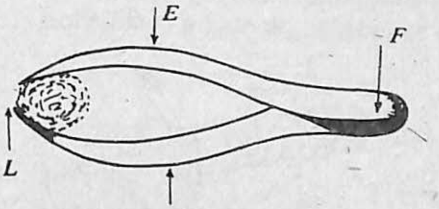
(e) Paper cutter

Fig. 6.7 Levers of the second order

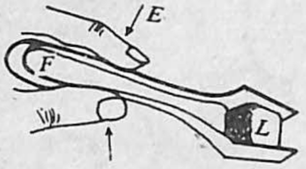
shovelling coal. The load arm is longer than the effort arm, so that a greater effort is needed to overcome a small load. In forceps, a greater effort is used in lifting a small weight. In this type of lever the mechanical advantage is always less than 1.



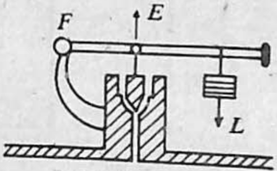
(a) The effort is applied in between the load and the fulcrum



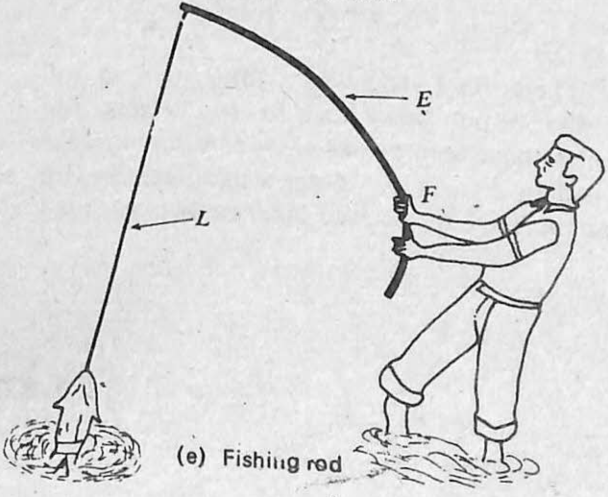
(b) Forceps



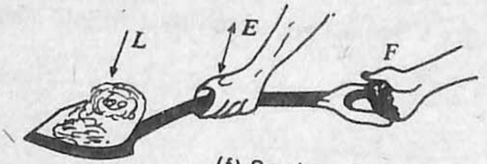
(c) Sugar tongs



(d) Safety valve



(e) Fishing rod



(f) Spade

Fig. 6.8 Levers of the third order

6.6 Other Machines

We come across many other machines in everyday life. Some you may not even recognise as machines.

A **wheel and axle** (Fig. 6.9) is used for lifting heavy loads, employing a small effort.

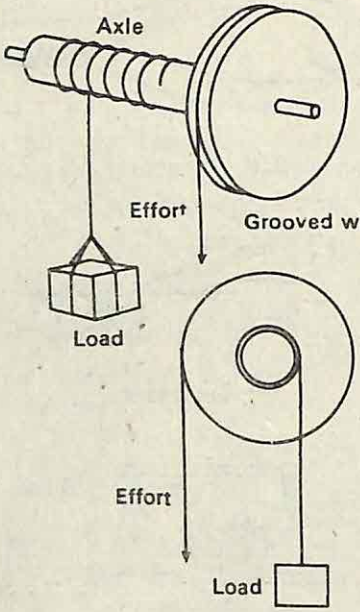


Fig. 6.9 Wheel and axle

The **inclined plane** (Fig. 6.10) is used to roll drums or pull heavy loads to great heights. You might have seen planks of wood being used for loading a truck. A scooter is usually pushed up an inclined ramp. The same method was used by the Egyptian in ancient times to pull heavy stones in building the pyramids.

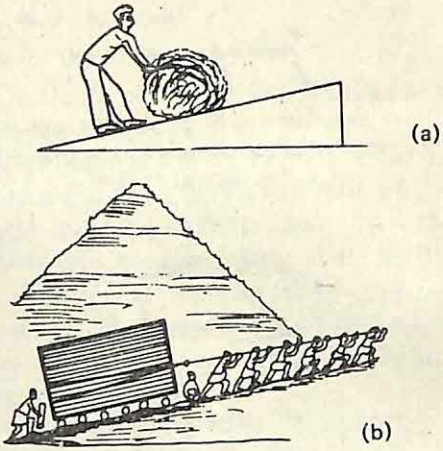


Fig. 6.10 The inclined plane

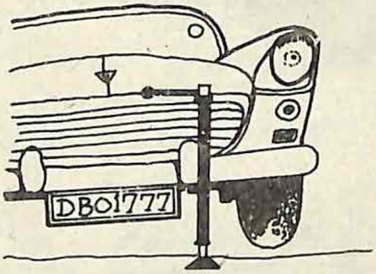


Fig. 6.11 The screw jack

The **screw jack** is another simple machine which is used to raise cars and lorries (Fig. 6.11). The mechanical advantage of a screw jack is much greater than 1. This enables us to easily lift up a heavy car.

EXERCISES

1. (i) What do you mean by a simple machine? ______________________

____

____

(ii) Give three reasons for the use of a machine. ______________________

2. What is meant by 'mechanical advantage'?

3. (i) What is meant by the efficiency of a machine?

(ii) Why is the efficiency of any machine always less than 1?

4. (i) What is a lever?

(ii) Which are the three types of levers? give one example of each.

5. Draw a diagram of each of the following types of levers. State to which type (order) each belongs.

(a) Physical balance_____ (b) Nut cracker_____ (c) Wheel barrow_____

6. (i) What is the mechanical advantage of a simple pulley? ______

(ii) In what way is a pulley useful as a machine? ______

______

7. Name two simple machines other than the lever and the pulley. ______

______

8. Fill in the blanks.

(i) Mechanical advantage of a lever = ______ arm/ ______ arm.

(ii) The force that we a apply to a machine is called the ______; the force which a machine overcomes is called a ______.

(iii) In a lever a weight of 50 kg-f balances a weight of 30 kg-f. The distance from the fulcrum to the 50 kg-f weight is ______ (equal to/less than/greater than) the distance from the fulcrum to the 30 kg-f weight.

(iv) If there is some friction between the axle and the block in a pulley, its mechanical advantage is ______ (less than/equal to/greater than) 1.

7

Heat and Its Transfer

The food that we eat provides the chemical energy which changes into heat to keep our body warm. Gas, coal or wood provide heat to cook our food. Many other jobs we do, and those which machines do for us, require fuel; the fuel burns giving off heat.

7.1 Solar Heat

The most abundant and free source of heat energy is the Sun. It provides us warmth during the day. The heat may make our life uncomfortable during summer but it is most welcome during winter. Plants use heat energy from the Sun for their growth. Man and animals eat and live on plants; without this heat, life on Earth would be impossible.

Experiment 1. On a clear sunny day hold a magnifying glass (converging lens) in one hand and a piece of carbon paper in the other just below the lens. Move the lens closer or further away to form a small bright spot on the paper (Fig. 7.1). If you hold your hand steady for a while, the paper starts smouldering.

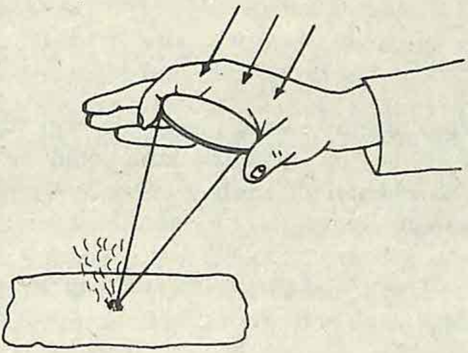


Fig. 7.1

When all the heat reaching the lens is thus brought to a point, it can burn a hole into the paper. Imagine how much energy must be reaching the total surface of the Earth each day; it has been calculated that this would be equal to the heat energy released by burning more than 100 million million tonnes of coal!

Another method to collect the heat spread over a wide surface is to use absorbers. Solar heaters use heat from the Sun to warm water. Fig. 7.2 shows a solar heater.

7.2 Change of State

We often see that water in ponds dries very quickly during summer. Water from the sea changes into vapour and forms clouds. Water changes into vapour not only over ponds, lakes, rivers and oceans, but also on the surface of soil, skin and wet clothes hung for drying. The heat needed for this evaporation comes from the Sun.

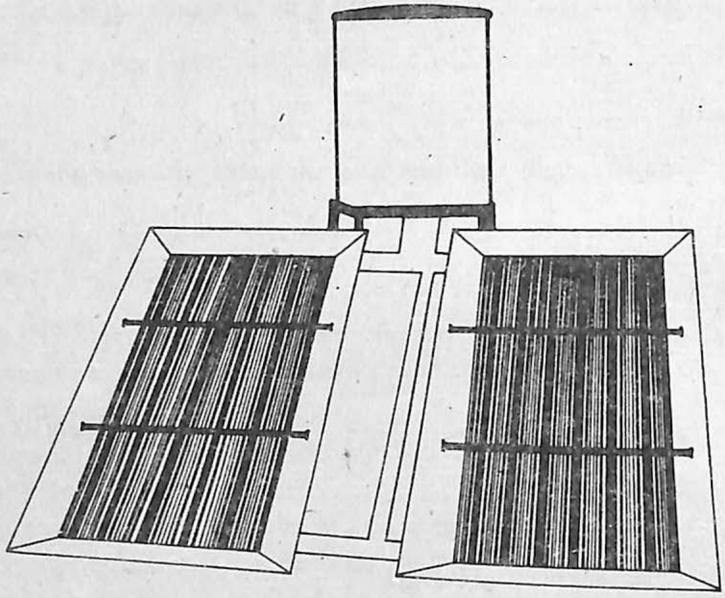
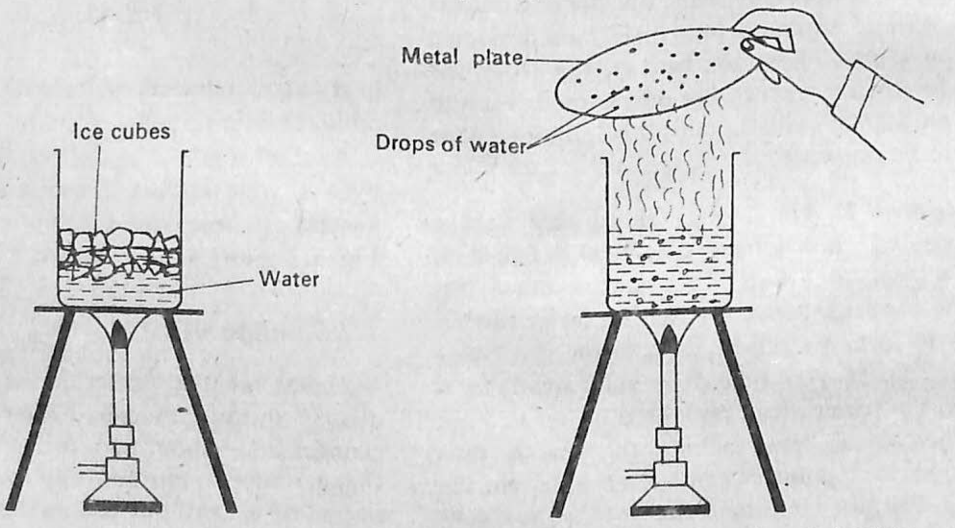


Fig. 7.2 Solar water heater

When a candle burns, have you noticed the wax at the top changing into liquid? If the candle is blown off, the liquid wax changes back into solid.

Experiment 2. Take a few cubes of ice in a beaker. Observe how the ice begins to melt when the beaker is kept in the open. The cubes take heat from the surroundings and melt into water. You can quicken this change by holding the beaker over a burner (Fig. 7.3a). Continue to heat the water and it starts changing into vapour. When sufficiently hot, it begins to boil and changes into steam.

Now hold a metal plate above the beaker; the vapour gathers in the form of drops of water



(a) Ice melts to form water on heating

(b) Water changes to vapour on heating. The vapour condenses back to water on cooling

Fig. 7.3

(Fig. 7.3b). If the water is cooled sufficiently in a refrigerator, it changes back into solid ice.

Solid, liquid and gas are called the **three states of matter**. Most materials change from solid to liquid, and from liquid to gas, when heated; they change back to liquid and solid state when cooled. Change of state is one of the noticeable effects of heat. These changes could be shown in the following way:

$$\text{ice} \xrightarrow{\text{heat}} \text{water} \xrightarrow{\text{heat}} \text{vapour} \xrightarrow{\text{cool}} \text{water} \xrightarrow{\text{cool}} \text{ice}$$

7.3 Temperature

In all the above experiments we notice that heat from the Sun and other sources makes objects hot; removal of heat makes them cold. *Temperature is the name given to the degree of 'hotness' or 'coldness' of an object on a chosen scale.* A thermometer is used to measure the temperature of any object.

Experiment 3. Get hold of a liquid-in-glass thermometer (Fig. 7.4) and place it on the table for a minute or two. Note the level of liquid in the stem which indicates the normal room temperature. Hold the thermometer in your closed fist, and observe the liquid level. As the level rises, it shows an increase in temperature due to heat received from your hand.

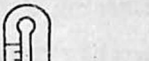


Fig. 7.4 A thermometer

The temperature is read on a chosen scale. The most commonly used scale is the **Celsius** or **Centigrade scale**. The unit of this scale is **degree Celsius** or °C. If a person has high fever, one can easily know about this by touching his body. However, our sense of touch would be very unreliable if the person has slight fever. Normal human body temperature is about 37 °C, and can be read by holding the bulb of a thermometer in the mouth, below the tongue.

7.4 Cooling by Evaporation

Normal body temperature remains remarkably constant whether we do physical exercise or take rest. When we run, chemical energy in food quickly changes into heat energy and makes our body warm; sweating is a natural process which helps bring down the temperature to normal.

Experiment 4. Use a dropper or a glass tube to place a drop of ether or alcohol on your open palm. Your hand will feel cool as the liquid evaporates. Tie some cotton around the bulb of a thermometer; dip the bulb in some ether or alcohol, and then hold it out in the open and observe the drop of mercury level in the stem.

7.5 Heat Radiation

It is a familiar observation that when we switch on a lamp, it gives light as well as heat; a heater used primarily to give heat, also gives out light. The Sun gives us both light and heat. In fact, any object which becomes sufficiently hot gives out light. When a heater is switched on, or an iron bar is placed in a fire, it first begins to glow with a dull red colour when the temperature reaches about 550°C. As the temperature is further increased, the colour changes to bright red. The temperature of a filament of a bright glowing lamp is more and it gives a yellow-hot or white-hot light. The fact that the colour of a hot object changes with temperature is useful to estimate the temperature of distant objects. The surface temperature of the Sun has been estimated to be about 5500°C.

Heat energy from the Sun reaches us through the intervening 'space' in the form of **radiation**, or more correctly **infra-red radiation**. Infra-red and light have many similar properties. They can both be reflected; they can be brought to a point by a lens showing a property called **refraction**. Infra-red radiations travel in a straight line, a fact which can be proved by placing a cardboard between our eye and the Sun, thus stopping both heat and light. Since the intervening 'space' between the Sun and the Earth is almost empty, it is obvious that infra-red and light require no medium to pass through.

Light itself is invisible but makes other objects visible when it falls on them and gets reflected to our eyes. In the same way infra-red itself is not hot; objects which receive infra-red radiation absorb the energy and become hot.

During a total solar eclipse, both light and infra-red are cut off at the same time; the drop in temperature is sudden which proves that infra-red radiations and light travel with the same speed.

Experiment 5. Take two identical tin cans; paint one of them black and keep the other shining from outside. Fill them half with water. Cover them with cardsheets which hold a thermometer, and space them on a table in the open under direct sunlight. (This ensures that infra-red radiations from the Sun strike them directly.) Note the mercury levels in the two thermometers which would show that the temperature of water in the beginning of the experiment is the same (Fig. 7.5). In a few minutes, the thermometer in the black can will record a higher rise in temperature.

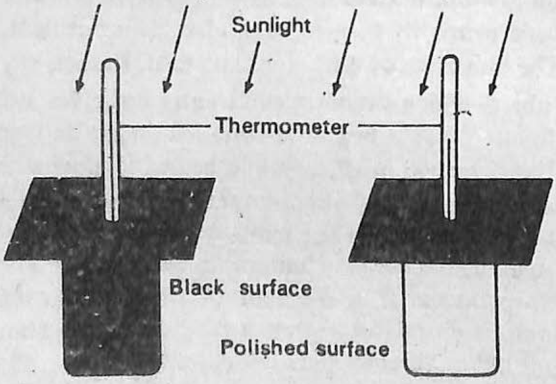


Fig. 7.5 A black surface absorbs heat radiations better than a polished surface

Now replace the water in both the cans with hot water. Place them in the shade and record the temperature. In a short time it would be noticed that the water in the black can cools faster than that in the polished can.

The first experiment shows that a black surface absorbs infra-red better than a polished surface. The second experiment shows that a black surface radiates infra-red more effectively than a polished surface. White or polished surfaces are thus good reflectors but poor radiators of radiant heat. For the same reason, white and faint-coloured clothes are preferable in summer than dark coloured clothes. In winter, dark clothes feel warmer. The back of a refrigerator and hot plates are coloured dull black to radiate heat effectively.

All objects emit heat radiation. Objects at higher temperature emit more heat than those at lower temperatures. The net result is that heat flows from high towards low temperature.

7.6 Conduction

When two objects having a difference in temperature are in contact, or when one end of an object is heated while the other is cold, heat flows directly through the object. This process is called **conduction**.

Conduction is a process in which heat energy received at one end of an object is transferred to the other end from particle to particle; the particles themselves do not move.

Experiment 6. Fix a metal rod horizontally with the help of a retort stand. Cut several sections of a candle and fix them to the rod along its length as shown in Fig. 7.6. Heat one end of the rod. You will see that the candle pieces fall one by one from the heated end. As heat reaches a wax piece, it melts and the piece falls down. This shows that heat is transmitted along the rod from the hot end towards the cold end.

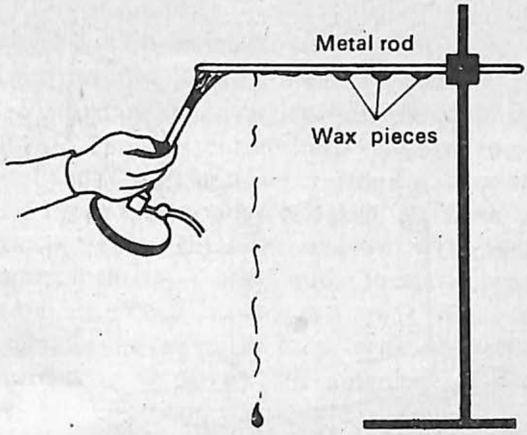


Fig. 7.6 Heat is conducted from the hot end towards the cold end

Experiment 7. Hold one end of a thick piece of copper wire and place the other end over a burner flame; very soon the whole wire becomes uncomfortably hot to hold. If the experiment is repeated with a similar piece of iron, it would be noticed that heat takes more time to reach the other end. The end in the flame may become red-hot but the other end could still perhaps be held. If a glass rod is used instead, the end in hand remains comfortably cold.

All metals conduct heat but the above example shows that copper is a much better conductor of heat than iron. The glass rod in the above example allows very little heat to flow through it and is called an **insulator** or a **bad conductor** of heat. Pans, kettles and other cooking utensils are made of metal so that they can quickly and effectively transfer heat which they receive from the source below, to the material inside. The handles of kettles, soldering irons and pans are often made of insulators such as wood or plastic so that they do not become very hot and can be easily held in hand. You may have seen blocks of ice covered with saw dust to prevent them from melting. Saw dust is an insulator of heat and prevents heat from reaching the ice.

All substances which are liquid at normal temperature, except mercury, are bad conductors of heat. The following experiment shows that water is a very poor conductor of heat.

Experiment 8. Put some ice inside a boiling test-tube. Push a piece of wire gauze through the tube so that it traps the ice inside. Now fill up the tube with water and hold the open end over a burner flame carefully. The water soon begins to boil but the ice is still not fully melted (Fig. 7.7). If the experiment is repeated by heating the tube from below with ice floating on top, the ice quickly melts.

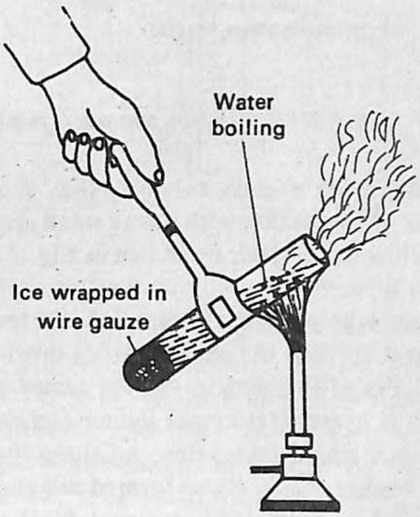


Fig. 7.7 Water is a poor conductor of heat

Actually, water is a poor conductor of heat as shown by the fact that when it is boiling at the top, ice trapped below does not melt. Yet it is a common experience that when water is heated from below it gets hot easily. Heat therefore flows easily upwards in liquids. This suggests that there is another mode of transfer of heat in liquids.

7.7 Convection

Convection is a mode of transfer of heat in which heated particles of a fluid (liquid or gas) go from one place to another. As mass movement of particles is not possible in solids, convection cannot take place in them.

Experiment 9. Fill a beaker with water and drop a large crystal of potassium permanganate at its bottom on one side. This can be done con-

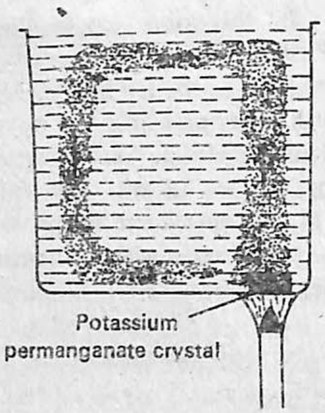


Fig. 7.8 Convection currents in water

veniently using a glass tubing. Now, heat the bottom of the beaker with a very small gas flame just below the crystal, as shown in Fig. 7.8.

It is observed that coloured water rises from the place where the heat is applied. On reaching the top it spreads out and descends down along other sides of the beaker. As the water at the bottom is heated it becomes *lighter* and rises up. The cooler upper layers descend along the sides of the beaker. Currents so formed are known as **convection currents**. This process continues till the whole of the water gets heated.

Experiment 10. Convection in air is shown by using an apparatus shown in Fig. 7.9. It consists of a rectangular box with two wide glass tubes projecting from the top and having a removable glass front.

Place a small lighted candle at the base of one of the tubes and hold a smouldering taper

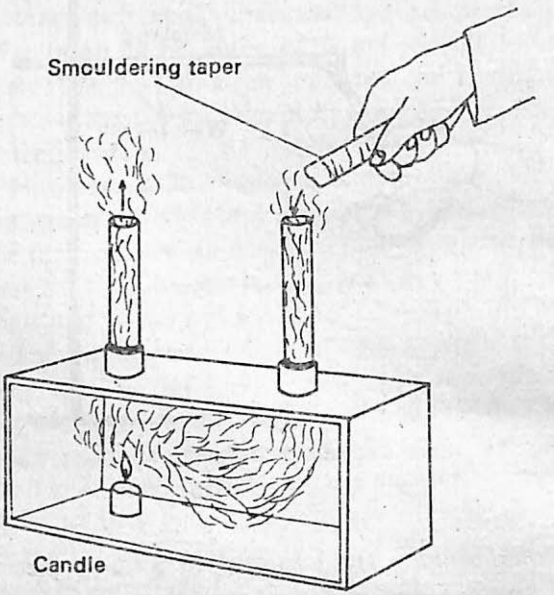


Fig. 7.9 Convection currents in air

at the top of the other tube. Smoke is seen entering down the tube over which the smouldering taper is held and rising above the candle and leaving from the tube above it.

Air above the candle becomes warmer and *lighter* and moves up; its place is taken by fresh air sucked in from the other tube.

Examples of Convection

A common example of convection in nature is the setting up of land and sea breezes. At coastal places the land gets hot quicker during the day; as the air above it becomes warm and rises, its place is taken by a cool breeze flowing from the sea. At night the land cools quickly when a

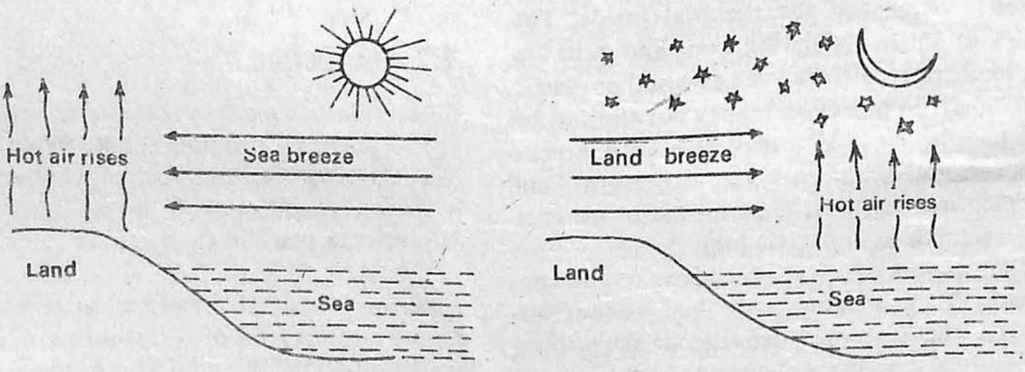


Fig. 7.10 Land and sea breezes

breeze flows from land to sea (Fig. 7.10). Coastal areas therefore have a temperate climate.

Ventilation is a practical example of the use of convection currents to keep insides of rooms cool and fresh. The air we breathe out is warmer and rises while its place is taken by fresh air coming inside from the windows. The ventilators at the top provide outlet for the stale and warm air. Ocean currents and trade winds are examples in nature of large scale convection currents set up due to this difference of temperature in air and water.

The engines of scooters and motor cycles become hot as the machine runs. However, as the vehicle travels with speed, the surrounding air carries away the heat; this natural cooling is achieved by enabling the engine to come in contact with air easily.

In the case of motor cars and other heavy vehicles, the engine *E* (Fig. 7.11) is surrounded by a jacket through which water circulates carrying away the excess heat. This circulation due to convection currents is aided by cooling of water at the radiator *R*. A fan *F* behind the radiator sucks in air, thus helping water in the radiator to cool quickly.

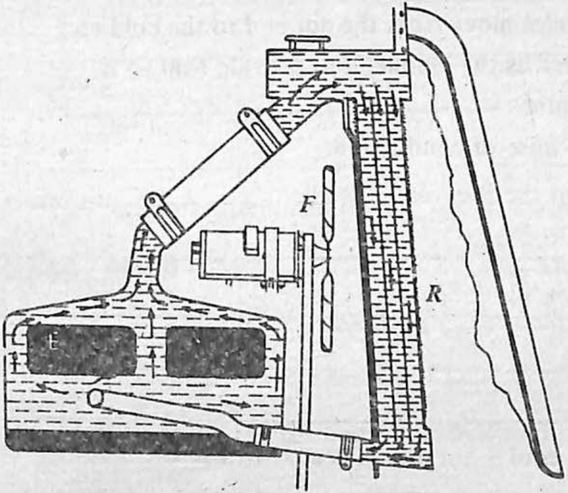


Fig. 7.11 Cooling system in cars

Hot water system in many hotels and houses is based on the principle of convection. It essentially consists of two tanks; the lower tank (Fig. 7.12) is called the boiler. Hot water from the boiler rises and goes into the upper tank, from where it is taken out for use. As the water is used up, cold water from the supply system enters the circulation to be heated in the boiler.

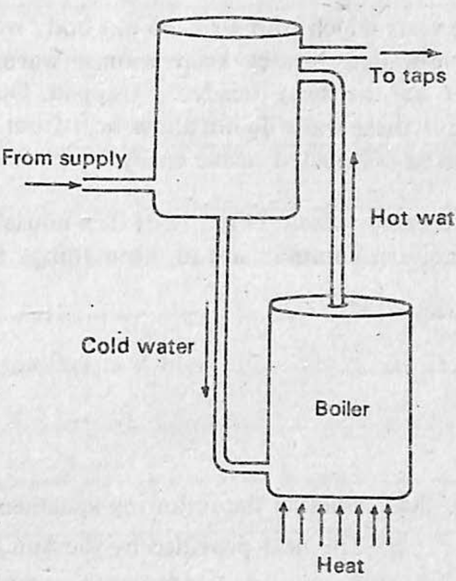


Fig. 7.12 Principle of hot water system

It is important to know that both water and air are bad conductors of heat. If they are trapped and no movement is allowed, they behave as good insulators like felt or feathers. Open

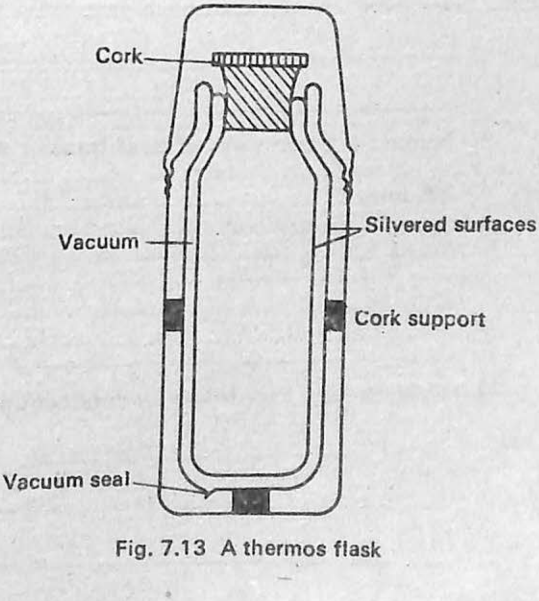


Fig. 7.13 A thermos flask

string vests which trap air keep our body warm. Double-walled houses keep rooms warm in winter as the heat inside is trapped. During summer these walls do not allow heat from outside to be conducted inside easily.

A thermos flask (Fig. 7.13) is a household appliance in common use to keep things in it warm or cold. It is a double-walled flask. Air between the walls is removed and they are polished. As both conduction and convection require particles for their transfer, the vacuum stops heat flow either way considerably. The polished surfaces reflect heat back thus minimising radiation. Loss of heat by evaporation is stopped by closing the flask using a cork.

EXERCISES

1. State whether the following statements are true or false.
    - (i) The heat provided by the Sun is so spread out that it cannot be put to any use.
    - (ii) Temperature measures how hot a body is.
    - (iii) The colour of light emitted by a hot object gives an indication of its temperature.
    - (iv) Good reflectors of heat are poor radiators.
    - (v) In the process of conduction, the particles move from the hot end to the cold end.
    - (vi) Ice wrapped in a blanket will melt faster as the blanket will provide heat to it.
    - (vii) Convection can only be observed in liquids.
    - (viii) Land and sea breezes are produced because of conduction.
2. State three ways in which heat radiation from the Sun resembles light. ________

    ____

    ____

    ____

    ____
3. Name the three ways of heat transfer which cool a hot cup of tea. How can the cooling be minimised? ________

    ____

    ____

    ____
4. Explain how heat losses by conduction, convection and radiation are reduced in a thermos flask. ________

    ____

    ____

5. Explain why:

(i) A stone floor feels cold to bare feet in winter but a carpet in the same room feels comfortably warm.

(ii) White clothes are preferred in summer and dark clothes in winter.

(iii) If rods of iron and copper are held in the hand and their other end placed over a fire, the tip of the iron rod becomes red hot while that of the copper rod does not seem to glow.

(iv) A blanket wrapped around our body in winter keeps us warm, but heips a block of ice not to melt.

6. (i) Why is the freezer unit of a refrigerator at the top?

(ii) Why is the back of a refrigerator painted dull black?

7. (i) Draw a labelled diagram of an experiment to show that water is a poor conductor of heat.

(ii) How does water get heated easily when a container full of water is kept over a burner?

____

____

____

8. Why do coastal areas have a temperate climate? ______________________

____

____

____

8

Temperature and Volume Change

Heat energy causes many changes in objects. When a solid changes to liquid, or a liquid to gas, this change can be easily noticed. When it increases or decreases the temperature of an object we can touch it and feel the difference. A thermometer can also be used to note the change in temperature. The level of liquid in the thermometer stem rises due to an increase in volume of the liquid. Most materials expand in volume with rise of temperature, and contract on cooling.

8.1 Expansion of Gases

Experiment 1. Fix a tight-fit rubber cork and tube into a 500 ml flask and support it as shown in Fig. 8.1. Place a beaker filled with water under the open end of the tube and warm the flask gently over a flame. You will notice air bubbles coming out of the water showing thereby that air expands on heating. Now allow the flask to cool, and water is seen to rise up the tube; this shows that air contracts on cooling.

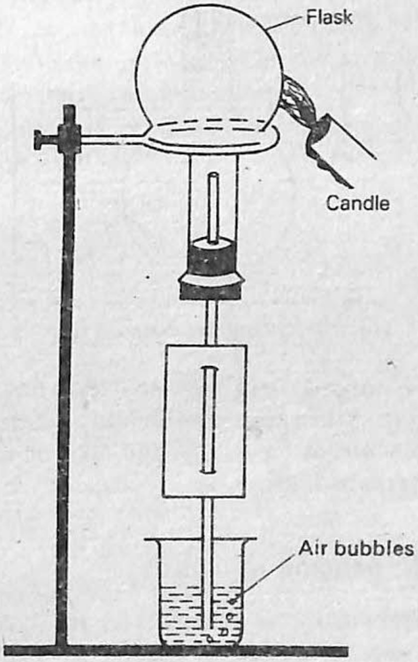


Fig. 8.1 Air expands on heating

Wait till the water level becomes steady. Now warm your hands by rubbing against each other and grasp the flask in your hands. Heat from your hands expands the air in the flask and forces water noticeably down the tube. If the flask is cooled by passing running water over it or by holding a few cubes of ice around it, the air contracts and water level rises up the tube. If you observe the water level carefully against a scale held next to it over a larger period of time, you will realise how the volume of air changes during the day.

8.2 Expansion of Liquids

Experiment 2. Add some fluorescein or coloured ink to water in a trough to make it clearly visible. Fill a 500 ml flask with it and fix on it a tight-fit rubber cork and tube. The water would rise a short way up the tube. Mark the level of water on a white sheet of paper held against the tube. Observe carefully any movement of the water level as the flask is immersed in a trough filled with hot water (Fig. 8.2).

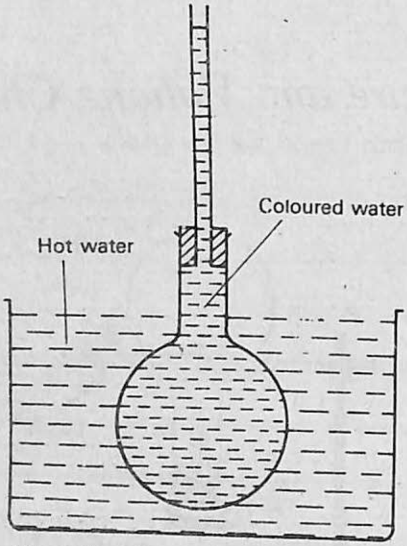


Fig. 8.2 Water expands on heating

It is noticed that the water level first drops slightly and then rises considerably. If the flask is taken out of the trough and allowed to cool, the level falls back.

8.3 Expansion of Solids

The slight drop of water level in the above experiment is caused by expansion of the flask when heated; the flask expands in volume first due to direct contact with hot water. The experiment also shows that water expands much more than glass. The expansion of solids is rather small, and carefully arranged experiments are required to show this effect.

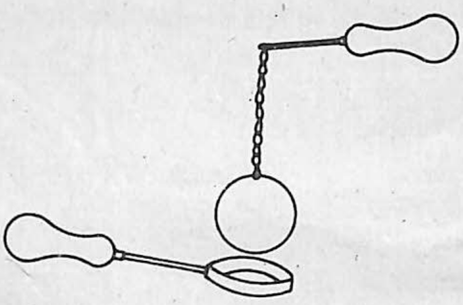


Fig. 8.3 The ball and ring apparatus to show that solids expand on heating

Experiment 3. A ball and ring apparatus (Fig. 8.3) can be used to show the expansion and contraction of a solid due to changes in temperature. At ordinary temperature the ball just passes through the ring. When the ball is heated over a flame, it expands and does not pass through the ring. However, if the ball is cooled, it contracts and passes through the ring again.

Now heat the ring and find out if the hole becomes bigger or smaller. This can be done by heating both the ring and the ball and observing if the ball passes through the ring. It is seen that the ring allows the ball to pass through easily when hot. This shows that both the inner and outer diameters expand on heating. This property is put to good practical use when a metal tyre is to be put on a cart or a train wheel. The tyre is heated and just slips on the wheel when hot. It contracts and tightly grips the wheel when it cools.

Experiment 4. To show the tremendous forces that come into play during expansion and contraction, a dramatic experiment can be performed using a bar-breaker apparatus (Fig. 8.4). It consists of a strong iron frame holding a steel rod. One end of the rod is threaded so that it can be

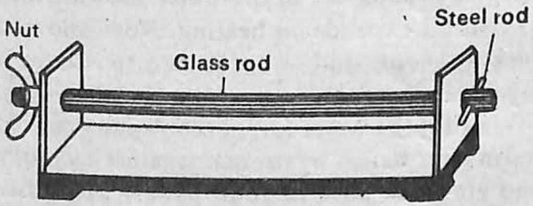


Fig. 8.4 The bar-breaker experiment to demonstrate the tremendous forces that come into play during expansion

screwed up. Through a hole near the other end is slipped a rod made of glass or wrought iron. The rod is first heated strongly and the nut tightened. As the rod contracts on cooling, it exerts a strong inward force which breaks the glass or wrought iron rod into pieces.

8.4 Examples of Expansion

Weathering is an example in nature of the effect of expansion and contraction of rocks which break into small pieces. If very hot liquid is poured in glass jars and tumblers, they are likely to crack. The inner walls suddenly expand while the outer walls, being cooler, do not. This causes a great force to act on the glass. Special kinds of glasses are now available which expand very little; as a result, the force developed is too small to break objects made from them. Telegraph wires are seen to sag between poles during summer due to their expansion.

Concrete roads, bridges and iron rails for trains are never made in one continuous piece but in short lengths separated by gaps to enable them to expand (Fig. 8.5). Without the gaps they may bend or bulge during summer. Long pipelines often have special sections to permit expansion and contraction without breakage. Pistons in car and scooter engines are fitted with springy rings so that while they hold the cylinders firmly during up and down movement, the expansion of pistons due to heat is accounted for.

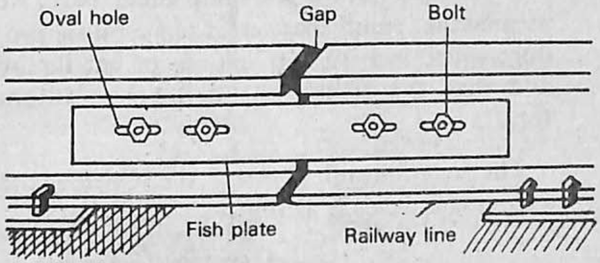


Fig. 8.5 Gap left between railway lines to allow for expansion

8.5 Bimetallic Strip

Different materials of the same length have different rates of expansion. An important application of the property is the bimetallic strip.

Experiment 5. A straight bimetallic strip which has two equal lengths of brass and iron riveted firmly together is taken. If it is heated or cooled considerably, it bends. When heated the brass strip is on the outside of the bent curve because brass expands more than iron (Fig. 8.6).

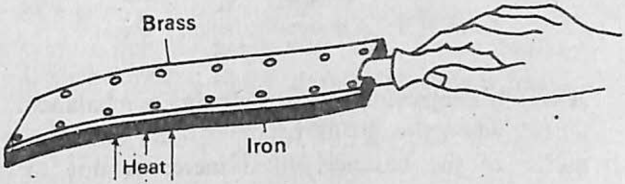


Fig. 8.6 Bimetallic strip

The bending effect is used in a **thermostat** to control temperature of electric irons, refrigerators and other automatic electrical appliances. Fig. 8.7 shows a thermostat fitted to an electric iron. At ordinary temperature the brass section of the bimetallic strip makes contact with the terminal, thus switching on the heater circuit. When the element of electric iron attains a desired temperature, the strip bends upwards sufficiently to break contact. As the iron cools down, the strip gradually returns to normal shape and touches the terminal. This switches on the iron again. A screw *S* enables the required setting for temperature by moving the terminal up and down.

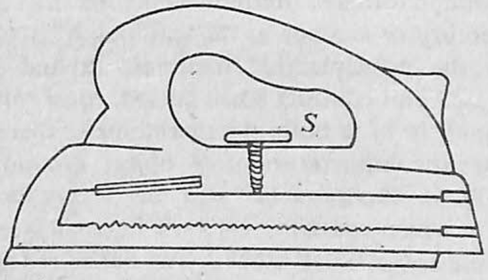


Fig. 8.7 Thermostat arrangement in an automatic electric iron.

Among the other applications of this bimetallic strip are flasher unit employed in cars, fire alarms and time control of clocks and watches.

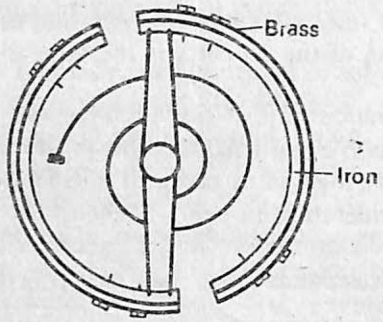


Fig. 8.8 A bimetallic balance wheel

A watch keeps time by the swinging of a balance wheel; when the spring becomes weak and diameter of the balance wheel increases due to expansion in summer, the watch would go slow. A bimetallic balance wheel (Fig. 8.8) ensures that temperature has no effect on these two factors.

8.6 Thermometers

A thermometer is an instrument specially designed to measure temperatures of objects. The most common forms of thermometers contain a liquid, mercury or alcohol, as the material. It is based on the principle that materials expand when heated and contract when cooled. Most of the liquid is in a bulb; the thermometer therefore gives the temperature of an object around the bulb. A thermometer also has a very narrow stem which contains very little liquid; it is sealed at the top after all air is driven out of the space at the top. The stem is marked to measure the temperature.

Like all other measurements, temperature is measured in comparison with some standard. Two temperatures which are reproducible and non-variable are taken as the **fixed points** for reference. These are

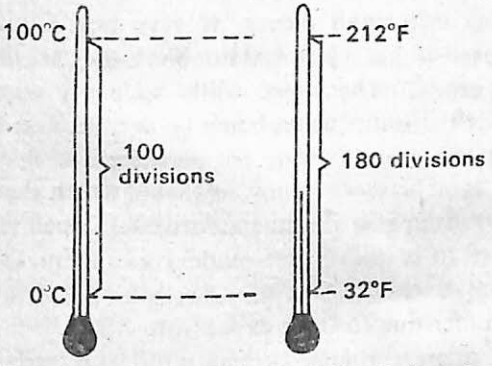
(a) The **lower fixed point** which is the temperature of pure melting ice at sea level.
(b) The **upper fixed point** which is the temperature of steam above pure boiling water at sea level.

The Celsius Scale (Fig. 8.9a)

On the Celsius scale, the two fixed temperatures are taken to be 0°C and 100°C and the distance between these two is divided into 100 equal parts. Each division represents a **degree Celsius** or C.

The Fahrenheit Scale (Fig. 8.9b)

On this scale the lower fixed point is 32 F and the upper fixed point is 212 F. The distance between the two fixed points is divided into 180 equal parts. Each part is called a **degree Fahrenheit** or F.



(a) The Celsius scale (b) The Fahrenheit scale

Fig. 8.9

While marking the scale into equal parts we assume that equal changes of temperature produce equal increases in volume of the liquid, and that the stem of the thermometer is uniform.

The relationship between the Celsius and Fahrenheit scales is as follows

$$\frac{C}{100}=\frac{F-32}{180}$$

where C is the temperature in degree Celsius and F is the corresponding temperature in degree Fahrenheit.

Example. Convert 122°F into °C.

Solution Given $F=122$

To find $C=?$

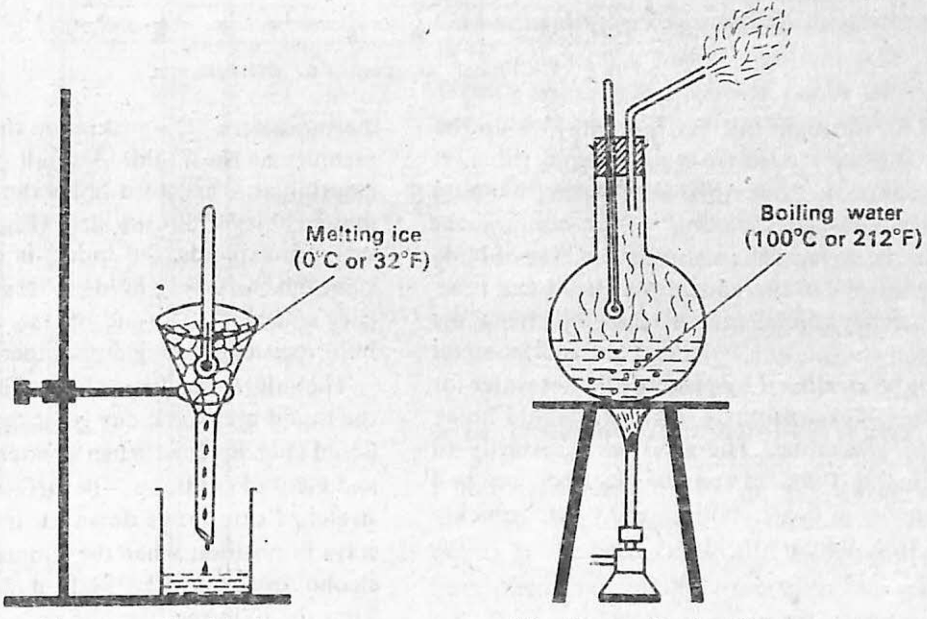
$$\frac{C}{100}=\frac{F-32}{180}$$

$$C=\frac{5}{9}(F-32) \quad =\frac{5}{9}(122-32)$$

$$=\frac{5}{9}\times 90=50°\text{C}$$ *Answer*

8.7 Sensitivity

A thermometer is sensitive when its degrees are far apart, i.e. even small changes in temperature can be noticed. Sensitivity can be increased by (a) increasing size of bulb, hence volume of liquid in it, so that the volume increase for a given temperature change is more: (b) reducing the bore of the stem, so that, for a given increase in volume, the liquid thread moves a greater distance; and (c) using a liquid which has a greater expansion rate. In this respect alcohol is better than mercury.



(a) Lower fixed point (b) Upper fixed point

Fig. 8.10 Marking lower and upper fixed points of a thermometer

8.8 Liquids in Thermometers

Mercury is most commonly used in thermometers because of the following reasons.

(a) It remains a liquid over a wide range (from −39°C to +357°C) of temperature, and hence can be used over most of this range.

(b) Its expansion is uniform over most of this range.

(c) It is a good conductor of heat; therefore, it quickly responds to changes of temperature.

(d) It is opaque; hence, its level can be read easily.

(e) It does not wet the glass stem: therefore it gives quick and accurate readings.

In very cold countries and for low temperature readings, alcohol is used as the thermometric material; it freezes at as low a temperature as −117°C. Alcohol also has the advantage that its expansion rate is about seven times that of mercury; it is therefore more sensitive. However, it wets the glass and has a low boiling point (+78°C). Since it is colourless it has to be coloured blue or red so that the level can be read easily.

8.9 Clinical Thermometer

The clinical thermometer, also called the doctor's thermometer (Fig. 8.11) is used for measuring body temperature and contains mercury. Since it has no other purpose, the temperature range on the thermometer is short: from about 35°C to 43°C (or 95°F to 110°F). There is a mark at 37°C (or 98.6°F) on the stem indicating the normal human body temperature. The body temperature is taken by placing the thermometer bulb under the armpit or under the tongue in the mouth. They however show a difference of about 0.5°C, the armpit temperature being lower.

The thermometer has a kink or constriction near the bulb (Fig. 8.11). When the bulb is placed under the armpit, expansion of mercury forces it through this narrow portion up the stem. When removed from the armpit, the mercury contracts; but this breaks the mercury thread at the constriction while holding the level in the stem. Thus a correct reading of body temperature can be made even after some time. The mercury thread can be reset by giving the thermometer a quick jerk. This thermometer cannot be *sterilised* by placing it in hot water for the force of expansion of mercury would break the thin glass tube. The glass has necessarily to be thin so that, in spite of glass being a bad conductor of heat, body heat can quickly reach the mercury inside.

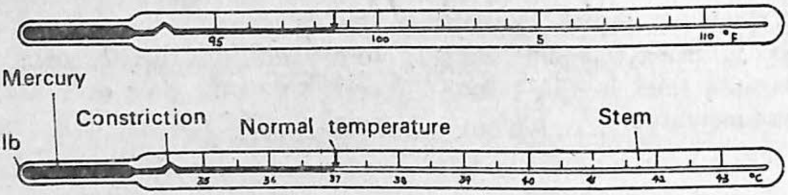
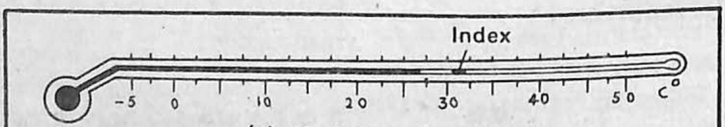


Fig. 8.11 Clinical or doctor's thermometer

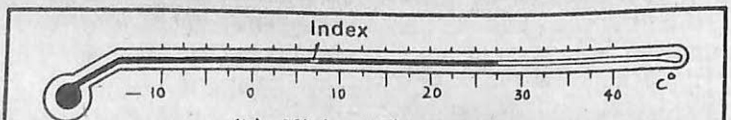
8.10 Other Thermometers

At times we want to know the highest or lowest temperatures attained during the day, but recorded at some later time. For example, the lowest temperature reached at night can be read conveniently only the following morning; the highest temperature during the day may be attained when we may not be looking at the liquid level. The need for continuous observation is avoided by a clever arrangement in these thermometers. The maximum thermometer uses mercury as the liquid. A small iron index with a spring attached to it holds the tube above the mercury level in the stem (Fig. 8.12a). When mercury expands, the index is pushed up the stem but the spring holds it in place when mercury contracts. The end of the index near the bulb registers the highest temperature reached.

The minimum thermometer uses alcohol as the liquid and the index is inside the level of the liquid (Fig. 8.12b). When the temperature falls and alcohol contracts, its surface, acting as a stretched skin, pulls down the index. The index stays in position when the temperature rises and alcohol expands. The end of the index away from the bulb registers the minimum temperature reached. In both these thermometers, a magnet is used to reset the index.



(a) Maximum thermometer



(b) Minimum thermometer

Fig. 8.12

8.11 Maximum and Minimum Thermometer

The Six's maximum and minimum thermometer serves a double purpose: to measure and record maximum temperature during day and minimum temperature at night. The bulb *A* (Fig. 8.13) contains the thermometric liquid alcohol, whose change in volume with temperature is primarily responsible for registering the minimum and maximum temperatures. Section *BC* contains mercury; above *C* there is alcohol which partly fills the bulb *D*, leaving the space above it empty to allow for expansion.

When alcohol in *A* expands due to rise in temperature, it pushes the mercury section, thus sending the steel index above level *C* upwards. The index enables the maximum day temperature to be read on the scale marked along the limb. When alcohol in *A* contracts due to fall in temperature at night, the mercury is drawn back pushing the steel index above *B* upwards. The index therefore gives the minimum temperature reached during the night, and this can be noted on the scale marked along this limb.

At any time of the day, mercury level in both the limbs is always the same and gives the room temperature.

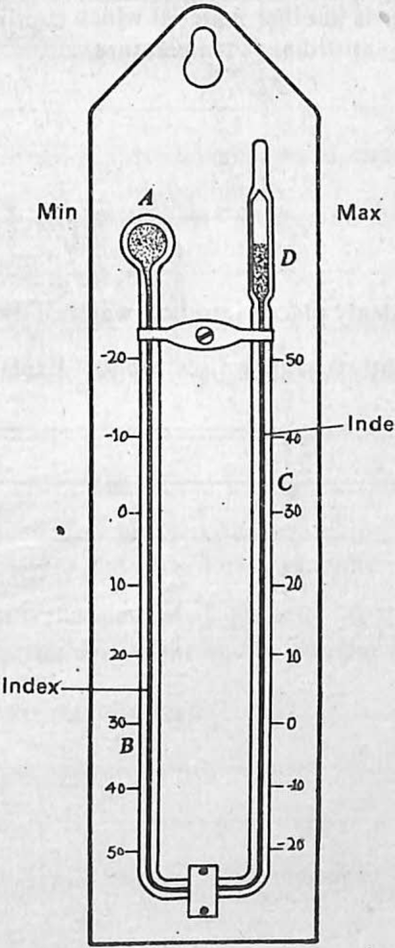


Fig. 8.13 Six's maximum and minimum thermometer

8.12 Unusual Expansion of Water

Water has several peculiar properties of which the effect due to change in temperature is significant. In the first place, while most liquids contract when they solidify, water expands on freezing. Thus ice floats on water. Secondly, when water at 0°C is heated, it actually contracts till 4°C and then starts expanding. Therefore, when

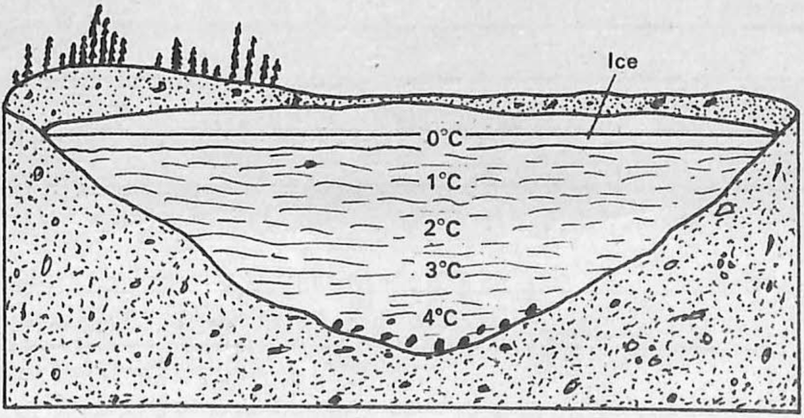


Fig. 8.14

a beaker temporarily holds ice and water at varying temperatures, the different layers set themselves as shown in Fig. 8.14.

In cold countries temperatures fall several degrees below zero. Thick ice sheet forms on top of lakes but the water below may remain at 4°C throughout winter, thus supporting marine plants and animals. Thus the unusual expansion of water is a fact of great importance in nature. Rubber is another material which contracts on heating at ordinary temperature.

EXERCISES

1. When the bulb of a laboratory thermometer is suddenly placed into hot water, it is observed that the mercury level in the stem first falls slightly and then rises rapidly. Explain. ____

2. Why does a bimetallic strip curve when heated? Draw a diagram to show how a bimetallic strip can be used to make a fire alarm. ____

3. (i) What is meant by Lower Fixed Point and Upper Fixed Point? ____

(ii) Convert

(a) 244°F into °C ____

(b) 25°C into °F ____

4. State two ways in which a clinical thermometer differs from a laboratory thermometer.

5. (i) Mention three advantages of mercury over alcohol as a thermometer liquid.

(ii) Under which circumstances is alcohol preferred over mercury in a thermometer?

6. Draw a clear labelled diagram of the Six's maximum and minimum thermometer.

7. How is the survival of aquatic life in cold countries dependent on the peculiar nature of expansion of water?

8. State whether the following statements are true or false.

(i) Gases expand more than solids or liquids.

(ii) Brass and iron have similar expansions.

(iii) Alcohol thermometers are more sensitive than mercury thermometers.

(iv) A mercury thermometer taken to the North Pole recorded a temperature of − 60°C.

(v) A doctor first sterilises his clinical thermometer by boiling in water before using it.

(vi) Water at 4°C is heavier than water at 3°C.

(vii) Water at 4°C is heavier than water at 5°C.

9

Rectilinear Propagation of Light

In an absolutely dark room, it is impossible to see around us. Strike a match or light a candle stick, and they give out some light, making objects around us faintly visible. If however we open a window to admit sunlight, the visibility becomes better. All objects which give out light, e.g., a burning match stick, a glowing electric lamp, the Sun, etc. are called **luminous** objects. Even the tiny firefly gives out a luminous glow.

Most of the objects that we see around us, e.g., chair, book, blackboard, etc. do not produce any light of their own. They become visible only when light from some luminous source falls on them. An object which does not give out light by itself is called **non-luminous.** Even the electric bulb becomes non-luminous when it is switched off.

9.1 Light and Sight

Is light the only thing required for seeing? In a dark room light from a luminous object enables us to see the other objects around us. Close your eyes and you will not be able to see the objects. A bind man cannot see even during daylight. Thus, no matter what light is available, eyes are essential to obtain vision. Among our senses, eyes have the special property of sight.

Although the first source of any light is a luminous object a great deal of light that reaches our eyes is the light sent back from non-luminous objects. The light from the Sun scattered by the Earth, trees, walls, our clothes, etc. makes our classrooms bright during the day. The Moon is a non-luminous object but it scatters the light that falls on it from the Sun. Unless a non-luminous object bounces off some light towards our eyes, it cannot become visible.

Quite often we say 'I see light in the room'. Actually we are seeing the illuminated parts in the room. In a cinema hall, a beam of light is 'seen' from the projector window to the screen; however, if we observe carefully, we notice dust and smoke particles floating in the path of the beam. If you shine a torch from one end to the other in a clean and dust-free room, you will hardly 'see' any beam of light. But, strike a duster against a hand to scatter chalk dust in the path of light, and the beam of light will appear to become visible. Light itself is not visible but the non-luminous objects in its path can be seen because they bounce off the light to our eyes.

9.2 Light Travels in Straight Lines

How does the beam of light in a cinema hall appear to travel? In the early morning the Sun's rays streaming in between the leaves, their path made visible by moisture and dust, appear to

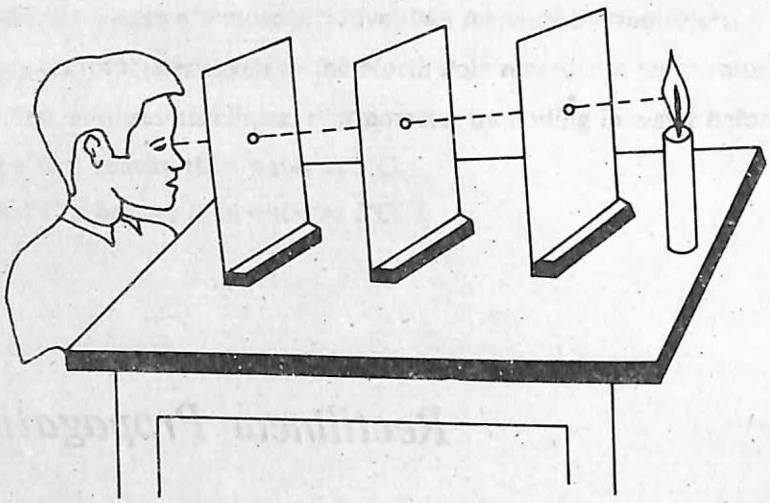


Fig. 9.1 Light travels in straight lines

go in straight lines. If you shine a torch at night in the open, the beam of light shows a straight path. Searchlights looking for an aeroplane, or the revolving searchlights used by circus shows, go outwards in straight lines.

Experiment 1. Take three cardboard pieces and make them stand vertically as shown in Fig. 9.1. Make a small hole in each of them at exactly the same height from the table. Place a lighted candle at one end so that its flame is at the same level as the holes. Look through the holes from the other end and adjust the cardboards so that the eye, flame of the candle and the three holes are in one straight line. You will then be able to see the flame.

Now slightly disturb one of the cardboards. Can you see the flame? Again adjust the cardboards so that the flame can be seen once more. You will observe that the flame can be seen only when all the three holes are in a straight line joining the flame and the eye. This shows that light travels in straight lines.

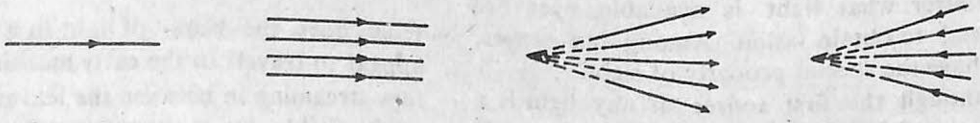
9.3 Rays of Light

All these examples are of broad beams of light. A very narrow path of light is called a **ray of light.**

A ray of light is shown in a diagram by a straight line, with an arrowhead showing the the direction in which the light travels (Fig. 9.2). A beam of light can be **divergent, parallel** or **convergent.** In these cases the rays which form the beam are spreading away, going parallel or coming towards each other, respectively. Rays reaching us from a very far off object, such as the Sun, are almost parallel to each other.

9.4 Opaque, Transparent and Translucent Objects

In Experiment 1 we saw that light cannot pass through cardboard. Hold your palm in the path of light between two cardboards and you can obstruct the light reaching your eye. Such



A ray of light A parallel beam A divergent beam A convergent beam

Fig. 9.2

objects through which we cannot see because they do not allow light to pass through them are called **opaque**.

Now hold a glass block in the path and find out if the flame is still visible. Such objects through which light can easily pass are called **transparent**. When we look outside a classroom through a window pane, we are looking through two transparent objects: glass and air.

Some window panes such as those of 'frosted' glass, are not very clear; they allow light to pass through them partially. You may have seen bulbs which give out light but whose filaments cannot be seen; such glass is called **translucent**. Greased paper, thin polythene sheets and tracing paper are examples of translucent objects.

9.5 Image

Experiment 2. Take a white opaque screen and place it at a distance from a burning candle. Hold a cardboard with a hole in it, in between the two (Fig. 9.3). You will notice that if the hole in the cardboard is very small, a clear and bright inverted picture of the flame is seen on the screen. This experiment will have to be performed in a dark room, or a bright source of light such as an electric lamp will have to be used, so that the lighted picture on the screen is clear. Every point of the object is sending out rays of light in all directions but only a very narrow beam of light passes through the hole. A ray of light starting from the point *P* will produce a corresponding bright point *R*; a ray travelling from *Q* will go straight through the hole and produce its corresponding bright spot on the screen at S. Similarly all bright spots on the flame will produce their corresponding bright spots on the screen. The picture or impression thus received on the screen is called an **image** of the candle. How does the size of the image vary if the screen is brought closer to the hole, the candle is moved closer to the hole, or the cardboard is moved closer to the screen? It is observed that when the screen is moved towards

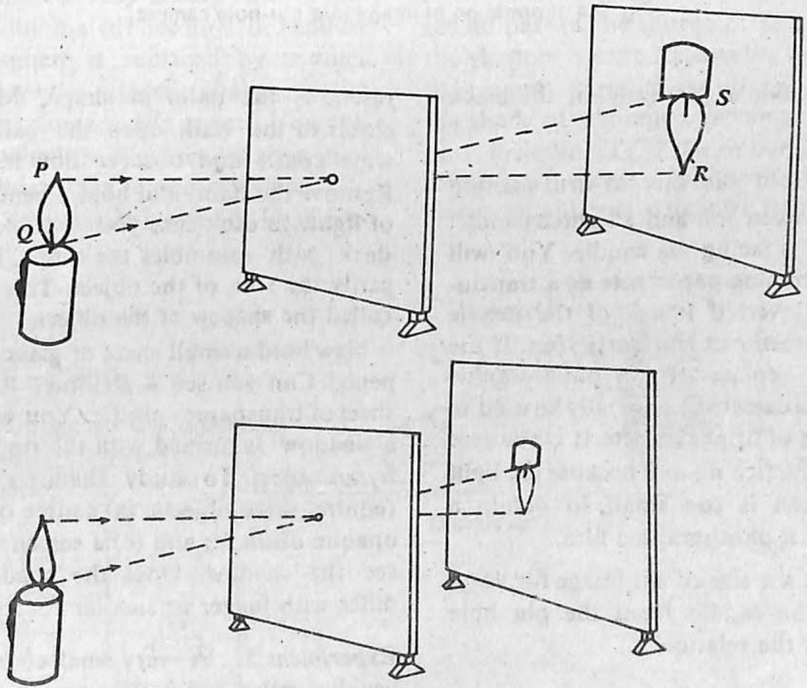


Fig. 9.3 Formation of image

the hole or the object is moved away from the hole, the size of the image is reduced. Measurement of the distances will show that:

$$\frac{\text{Height of image}}{\text{Height of object}} = \frac{\text{Distance of image from the hole}}{\text{Distance of object from the hole}}$$

9.6 Pin-hole Camera

Take a light-proof cardboard box and cut out a large square at one end. Paste a greased or tracing paper on the cut out portion. Make a square hole of about 5 cm side in the middle of the opposite surface and paste a black paper on it (Fig. 9.4). Now make a pin hole in the black paper.

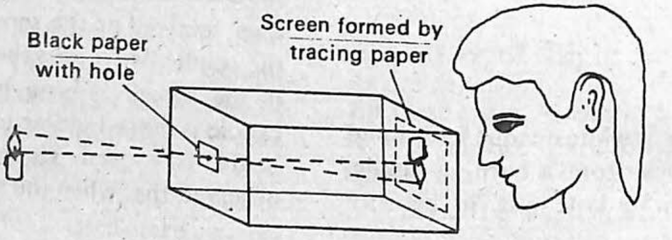


Fig. 9.4 Formation of image in a pin-hole camera

Experiment 3. Hold the box at arm's length such that it is between you and a lighted candle, and the pin hole is facing the candle. You will realise that the tracing paper acts as a translucent screen; an inverted image of the candle formed on the screen can be clearly seen. If the tracing paper is replaced by a photographic plate, this pin-hole camera can actually be used to take photographs of bright objects. It is however never used in practice mainly because the light reaching the screen is too small to obtain a bright picture on a photographic film.

If you measure the size of the image for varying distances of the candle from the pin hole you will find that the relation.

$$\frac{\text{Height of image}}{\text{Height of object}} = \frac{\text{Distance of image from the hole}}{\text{Distance of object from the hole}}$$

applies in this case also.

9.7 Shadows

When you stand in the sun, you can see your shadow formed on the ground. When you walk, the shadow moves along with you. Let us find out how these shadows are formed.

Experiment 4. Shine a torch towards a wall from a distance of about 2 metres in a dark room. If you hold your palm in the path of the light, you will see a dark patch against a bright background on the wall. Does this dark patch resemble the palm in shape? Move the hand closer to the wall, open the palm with fingers wide apart, and observe how its size changes. Remove the hand and hold a pencil in the beam of light. In each case you will notice that the dark path resembles the shape, but not necessarily the size, of the object. This dark patch is called the **shadow** of the object.

New hold a small sheet of glass instead of the pencil. Can you see a shadow? Repeat with a sheet of transparent plastic. You will realise that a shadow is formed with the stoppage of light by an object. To study shadows we therefore require three objects: (a) source of light; (b) an opaque obstacle; and (c) a screen on which to see the shadow. Does the shadow obtained differ with bigger or smaller sources of light?

Experiment 5. A very small source of light L, usually called a **point source**, is prepared by making a small hole in a cardboard box fitted

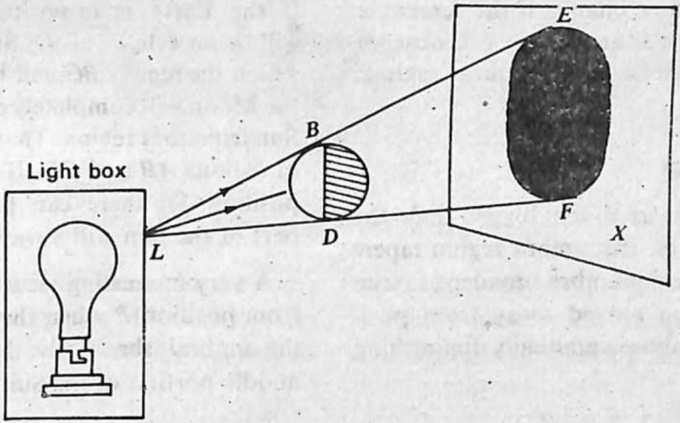


Fig. 9.5 Shadow of an opaque object formed by a point source of light

with an electric bulb. Such an arrangement is called a **light box.** Hold a sphere in the path of light and observe the shadow (Fig. 9.5). A ray from *L* to *X* will go straight to the screen and illuminate it. The rays *LB* and *LD* will go just grazing along the surface of the sphere and reach the screen at points *E* and *F*, respectively. Between *B* and *D*, all other rays of light will be stopped by the sphere. Why is only half of the sphere brightly illuminated? See how the shadow changes if the sphere is replaced by another obstacle. How does the shadow change if the obstacle is moved closer to the screen? You will notice that the shadow becomes smaller, and remains sharp and equally dark everywhere.

Experiment 6. Take a wide source of light prepared by making the hole in the light box bigger, and again study the shadow of the sphere. You will find that the shadow is not sharp this time. One faint and one dark shadow appear to be overlapping; actually there are two different parts of the same shadow. The dark part of the shadow between *E* and *F* (Fig. 9.6) receives no light at all and is called **umbra**; an eye situated at *A* within the shade of the umbra region would see no part of the source *L*. The fainter part of the shadow is called **penumbra** and in this part light is only partially cut off; an eye at *C* within the shade of penumbra region would see the top part, including *X*, of the source *L* but not the lower part which includes *Y*. Outside *GH* the screen would receive light from the entire source.

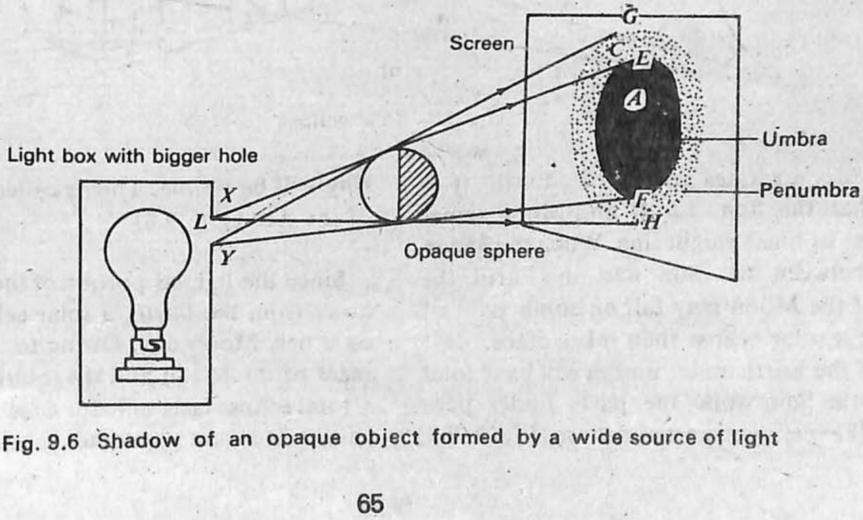


Fig. 9.6 Shadow of an opaque object formed by a wide source of light

How would the shadow change if the screen is moved away from the source? You will observe that both the umbra and penumbra regions become larger.

9.8 Solar Eclipse

If a source of light is much bigger than the obstacle, the shade of the umbra region tapers to a point, while the penumbra broadens as seen in Fig. 9.7a. A screen moved away from position S_1 to S_2 would show a gradually diminishing umbra.

As the Moon rotates round the Earth, it is natural that the Sun, Earth and Moon sometimes come in one straight line. When the Moon comes in between the Sun and the Earth, the shadow of the Moon may fall on some part of the Earth; a solar eclipse then takes place.

Parts of the Earth under umbra will have total eclipse of the Sun, while the parts under penumbra will experience partial eclipse (Fig. 9.7b).

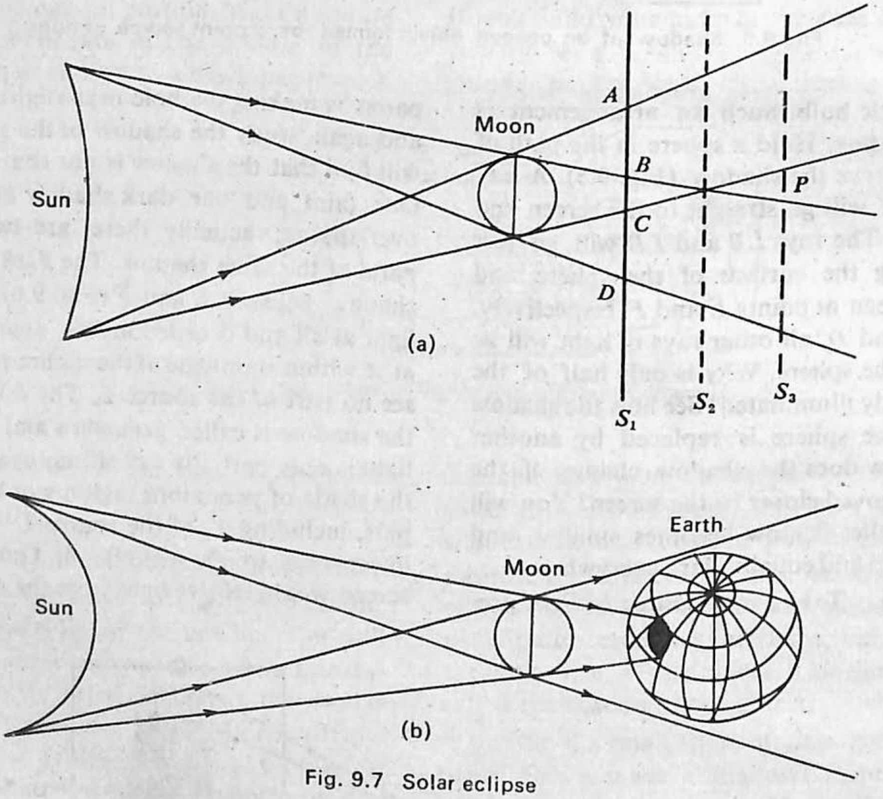
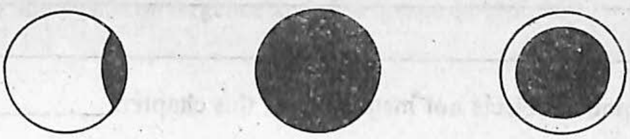


Fig. 9.7 Solar eclipse

If the Earth is in position S_1 (Fig 9.7a) there will be an eclipse of the Sun in region *AD*, of which the region *BC* will have total eclipse, i.e. the Moon will completely obstruct the view of the Sun from that region. There will be partial eclipse in regions *AB* and *CD*. If the Earth is beyond position S_2, there can be no total eclipse, i.e. part of the Sun will always be visible.

A very interesting view of the Sun can be had from position *P* when the Earth is just beyond the umbral shade; the Moon then covers the middle portion of the Sun while the outer bright ring will be visible. This is called **annular** eclipse of the Sun (Fig. 9.8).

Since the lighted portion of the Moon is facing away from the Earth, a solar eclipse takes place on a new Moon day. Owing to the fast movement of the Moon and the rotation of the Earth, a total eclipse lasts only for a few minutes; in any case, it is a rare phenomenon at a place because



Partial Total Annular

Fig. 9.8 Three types of eclipses of the Sun

the Sun, the Moon and the Earth do not come in a straight line on every new Moon day. (The Sun should never be viewed directly; it is safe to use very dark glasses.)

9.9 Lunar Eclipse

When the Moon occasionally passes through the umbral region of the Earth's shadow, it acts as a moving screen. A lunar eclipse (eclipse of the Moon) then takes place. The umbra of the shadow of the spherical Earth is always circular at its sharp edge. This was known as one of the earliest evidences for the spherical shape of the Earth. In Fig. 9.9 M_3 shows the position of a totally eclipsed Moon. If the Moon is at M_1 or M_4 in the penumbra region of the Earth's shadow, the eclipse is partial. Once the Moon is out of the Earth's shade, as in position M_5, it will be fully bright again. The eclipse of the Moon takes place on a full Moon night, and is far more frequent than the eclipse of the Sun because the Earth's shadow is far wider than that of the Moon.

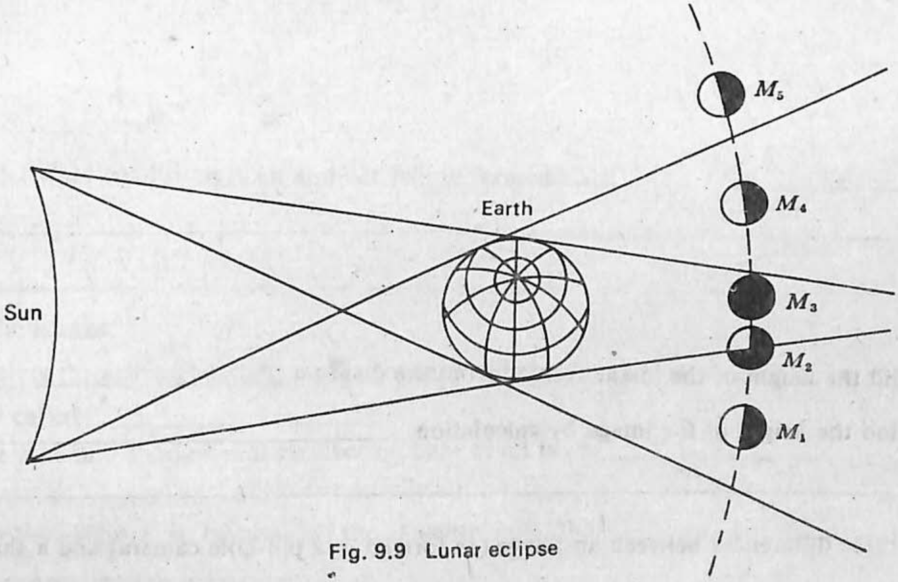


Fig. 9.9 Lunar eclipse

EXERCISES

1. (i) What is the difference between luminous and illuminated objects? ____________________

____

(ii) Name two luminous objects not mentioned in this chapter.

2. How does the image in a pin-hole camera change if

(i) the screen is moved further away from the hole?

(ii) the hole is made bigger?

3. Draw a neat scale diagram to show how a pin-hole camera forms an image of an illuminated object 1 cm high placed 6 cm away from the pin hole when the screen is 3 cm behind the pin hole.

(i) Find the height of the image formed from the diagram.

(ii) Find the height of the image by calculation.

4. State three differences between an image (as formed in a pin-hole camera) and a shadow.

5. Name a gas, a liquid and a solid which are transparent.

6. Draw a diagram to show the convergence and divergence of light rays.

7. (i) Construct a labelled diagram to show how a solar eclipse is formed.

(ii) Under what conditions is an annular eclipse formed? ________________________

____

____

8. Fill in the blanks.

(i) Objects through which light passes partially but through which we cannot see properly are called ________________ .

(ii) The part of a shadow that receives no light at all is the ________________ . In the ________________ light is partially cut off.

(iii) A solar eclipse is caused by the shadow of the ________________ on the ________________ .

(iv) A lunar eclipse takes place when the ________________ of the Earth falls on the ________________ .

10

Reflection of Light

A non-luminous object can be transparent, opaque or translucent. When light falls on it, one or more of the following may happen: (a) light may pass through the object; (b) light may be absorbed or (c) light may bounce off the object. Thus, transmission, absorption or reflection appear to be properties of the objects upon which light falls.

10.1 Reflection

Experiment 1. Spread a white sheet on top of a table in a dark room and place a light box at one end of the sheet. When light is switched on, you will notice the path of a beam of light made visible as it grazes along the sheet. Hold a narrow vertical slit in front of the beam so that a narrow beam of white light is obtained (Fig. 10.1). If you now hold a strip of mirror vertically to obstruct the beam of light you will observe that the direction of the beam is changed by the mirror.

The path along which light travels up to the mirror is called the **incident ray**. *The path along which light travels away from the mirror is called the* **reflected ray.**

Deflect the mirror to various angles and notice how this changes the direction in which the reflected ray travels. Can you reflect the ray at a right angle to the incident ray? Can you reflect the ray back along its path? In every case you will observe that the reflected beam is not scattered all around but the whole of it bounces away in a particular direction; and the particular direction depends upon how the mirror is placed (Fig. 10.2a). This is called **regular reflection.**

If the plane mirror is replaced by a metal

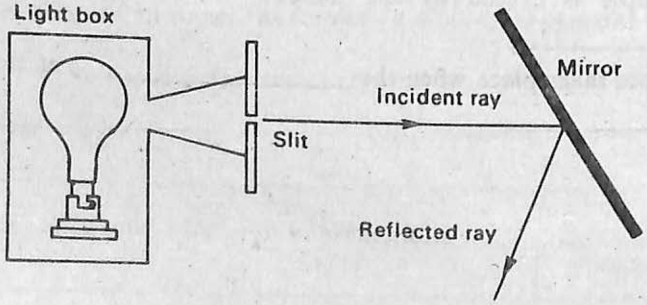
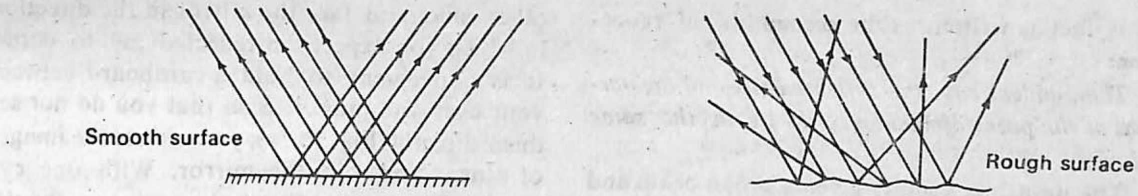


Fig. 10.1 Reflection in a plane mirror



(a) Regular reflection

(b) Irregular reflection

Fig. 10.2

sheet, you will see no reflected beam; the incident light is scattered in all directions (Fig. 10.2b). This diffuse or **irregular reflection** is entirely due to the unevenness of the surface on which light falls. We can feel the roughness of the surface; or see it by holding the metal sheet below a magnifying glass.

From the experiment it becomes obvious that regular reflection follows a certain pattern. Place a small white paper and draw on it a line *MP* along the mirror; next mark points *A* and *B* on the incident ray, and two other points *C* and *D* on the reflected ray as shown in Fig. 10.3. Now remove the paper, join *A* and *B* by a line and *C*, *D* by another. Produce both the lines and you will get the incident and reflected rays meeting at a point on the mirror line *MP*.

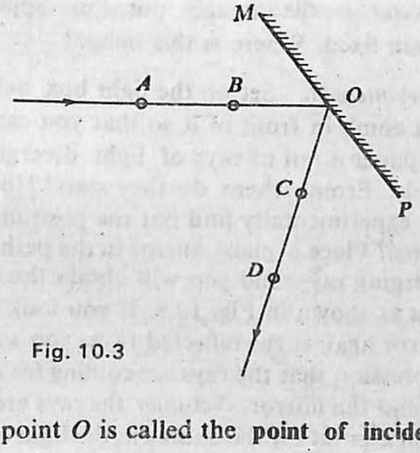


Fig. 10.3

The point *O* is called the **point of incidence.** Now use a protractor to measure the angles *AOM* and *DOP*. Repeat the experiment with different inclinations of the mirror to the incident ray, and obtain some more records. You will find that in all cases the two angles are almost equal.

10.2 Laws of Reflection

In practice, the angles selected are different. A line perpendicular to the mirror at the point of incidence *O* is drawn; this line *ON* (Fig. 10.4) is called the **normal.** The angle between the incident ray and the normal $\angle AON$ is called the **angle of incidence**; the angle between the normal and the reflected ray $\angle NOD$ is called the **angle of reflection.** These angles for all the records obtained from the experiments are equal. Thus, the direction in which the reflected ray bounces back from the mirror is seen to be predictable, and this is called the **first law of reflection:**

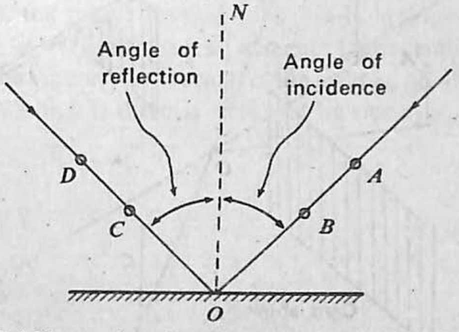


Fig. 10.4 The angles of incidence and reflection in a plane mirror.

Angle of incidence = Angle of reflection

Actually, there is one more law which fixes the direction of the reflected ray firmly. You will notice that only one plane can be drawn in which the incident ray and the normal lie; and this plane passes through the point which joins them. The reflected ray also lies in this plane (which in this experiment is the plane of the paper), and passes through the point of incidence O.

This fact is written as the **second law of reflection:**

The incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane.

The light box usually gives a broad beam and it is not easy to draw a ray accurately. The same experiment can be performed using very simple apparatus and in broad daylight.

Experiment 2. Fix a white sheet of paper on a soft board. Draw a line *MP* on the paper and stand a plane strip of mirror vertically along it. Now to fix the position of the incident ray we must mark at least two points. Therefore, two pins *A* and *B* are fixed vertically as markers about 5 cm apart such that a line joining them, which becomes the incident ray, is inclined at an angle to the mirror. Now place yourself on the other side and face the mirror in the direction in which you expect the reflected ray to come. It is convenient to hold a cardboard between your eyes and pins *A*, *B* so that you do not see them directly (Fig. 10.5a); you will see the images of pins *A* and *B* in the mirror. With one eye closed, fix two pins *C* and *D* as markers for the reflected ray such that the pins *C* and *D* and the images of pins *A* and *B* are in one straight line.

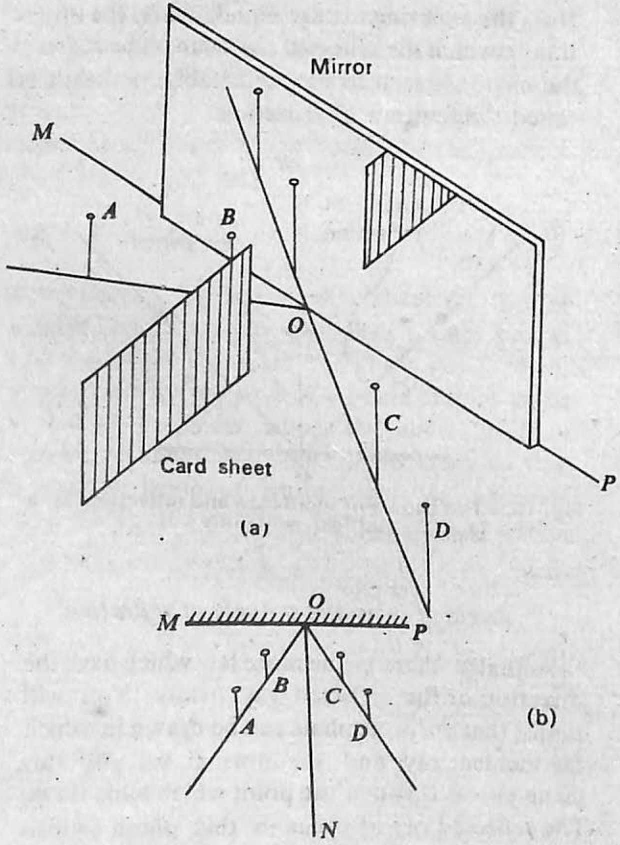


Fig. 10.5 Locating the incident and reflected rays in a plane mirror.

Now remove the mirror and the four pins. Join and produce *AB* to meet the mirror line *MP* at point *O*; Join and produce *CD* to meet the mirror; this line should also meet the mirror line at point *O*. Draw normal *ON* and measure the angles of incidence and reflection. Repeat the experiment for different inclinations of *AB*. You will find that in all cases the angle of incidence is equal to the angle of reflection.

10.3 Image Formed by a Plane Mirror

When you look into a plane mirror every morning you are looking at your own image in it. When you fix a pin in front of a plane mirror, you can easily see its image from different positions of the eye. Even when you change the position of your eyes—forwards, sideways or backwards—the image position appears to remain fixed. Where is this image?

Experiment 3. Set up the light box again and fix a comb in front of it so that you can see on the paper a fan of rays of light diverging outwards. From where do they start? How could you experimentally find out the position of the source? Place a plane mirror in the path of these diverging rays, and you will obtain the reflected rays as shown in Fig. 10.6. If you look into the mirror against the reflected rays, you will get an impression that the rays are coming from a point behind the mirror. Actually the rays are coming from a point on the source in the light box, after getting reflected at the mirror. If the reflected rays are traced backwards, we obtain the point from where the rays appear to diverge; this point is called the **image** of the source. Two reflected rays are sufficient to locate the position of the image.

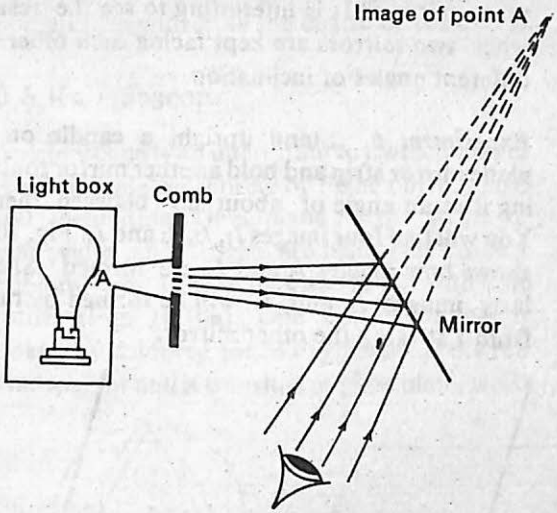


Fig. 10.6 Locating the image formed by a plane mirror

Experiment 4. The image formed by a plane mirror can also be located with the help of pins. Fix a white sheet of paper on a soft board and stand a plane mirror vertically along a line *MN*. Fix a pin vertically at a point *S* which serves as an object. Fix another pin *A* so that *SA* becomes an incident ray. Obtain its reflected ray *CD* by fixing two pins. Similarly take another incident ray *SB* and trace its reflected ray *EF*. Now remove the mirror and the pins. Produce both the reflected rays *CD* and *EF* backwards (Fig. 10.7) to obtain the point of intersection *I*, which is the image of *S*. Join *IS* and mark *O*, the common point on *IS* and *MN*. Measure the distance *IO* add *OS*, and the $\angle IOM$. You will find that $\angle IOM$ is a right angle, and $IO = OS$. Repeated experiments show that the perpendicular distance of the image and object from the mirror are equal. For example if you stand 1 metre away in front of a plane mirror, your image will be 1 metre behind the mirror. Thus, *the image formed by a plane mirror is as much behind the mirror as the object is in front of it.*

10.4 Virtual Images

The image formed by a plane mirror appears very much like the object and gives an impression of sending out light which we receive. Actually, this image has no real existence and the light is coming directly from the object after reflection at the mirror surface. No light reaches the image and it cannot be taken on a screen. Such an image is called a **virtual image.** In contrast, the image formed in a pin-hole camera is real; it is taken on a screen. Light actually reaches there, and it scatters the light in all directions which is directly received by our eyes.

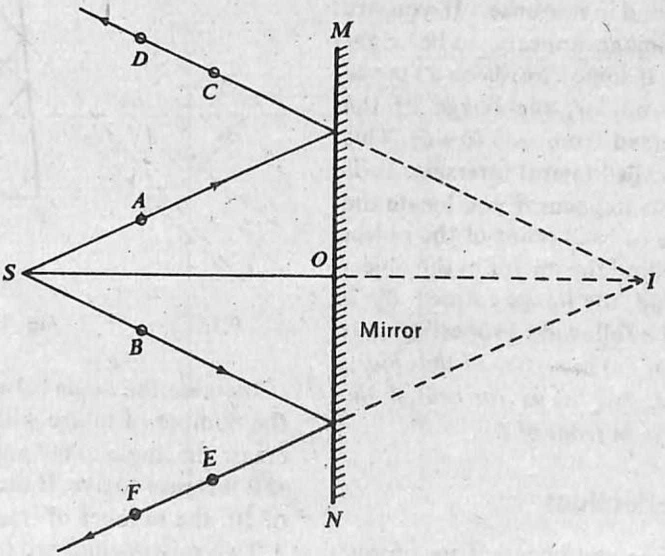


Fig. 10.7 Locating the image formed by a plane mirror with the help of pins

Experiment 5. Hold a pencil in front of a plane mirror and you will notice that its image is as big as the pencil itself. Try it with a book, your fingers or any other object. In all cases you will find that the size of the image by a plane mirror is the same as the size of the object. You will also notice that the image seen in a plane mirror is upright, whereas the image in a pin-hole camera is inverted.

However, the images in plane mirrors do get inverted in a peculiar way. Stand in front of a plane mirror and raise your right hand to shake hands with your image. You will find that the image raises its left hand in response. If you are left handed, your image appears to be right handed (Fig. 10.8). If some words on a paper are held close to a mirror, the image of the words appears reversed from side to side. This type of inversion is called **lateral inversion.** It is easy to see how this happens if you locate the corresponding image of each point of the object which is as much behind the mirror as the object is in front. To sum up, the image formed by a plane mirror has the following properties: *it is (a) virtual, (b) upright, (c) same size as the object, (d) laterally inverted, and (e) as far behind the mirror as the object is in front of it.*

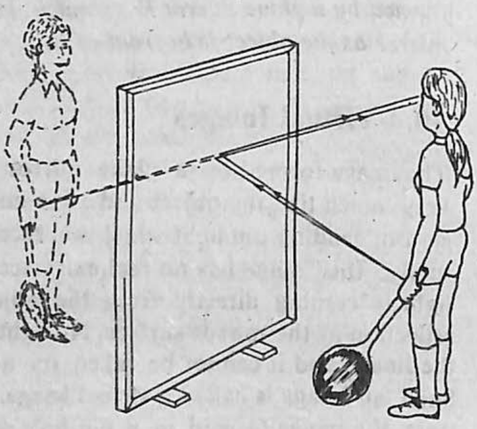
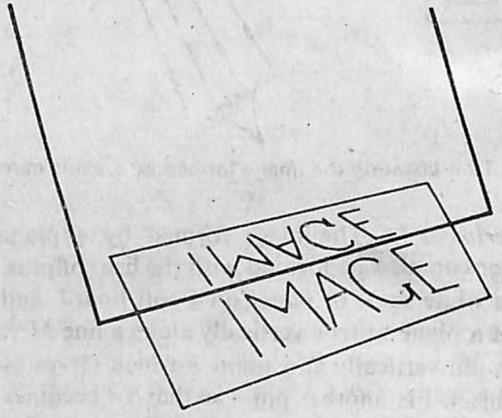


Fig. 10.8 Lateral inversion due to mirror

10.5 Multiple Reflections

One plane mirror gives one image of an object; how many images would we obtain with two plane mirrors? It is interesting to see the result when two mirrors are kept facing each other at different angles of inclination.

Experiment 6. Stand upright a candle on a plane mirror strip and hold another mirror touching it at an angle of about 80° between them. You will find four images I_1, I_2, I_3 and I_4. Fig. 10.9 shows how images I_1 and I_2 are formed. Similarly images I_3 and I_4 will be formed by rays from I striking the other mirror.



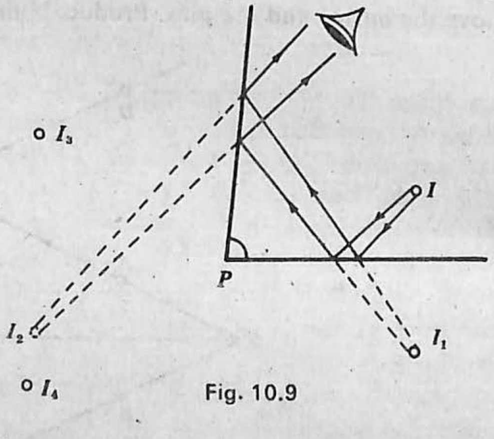


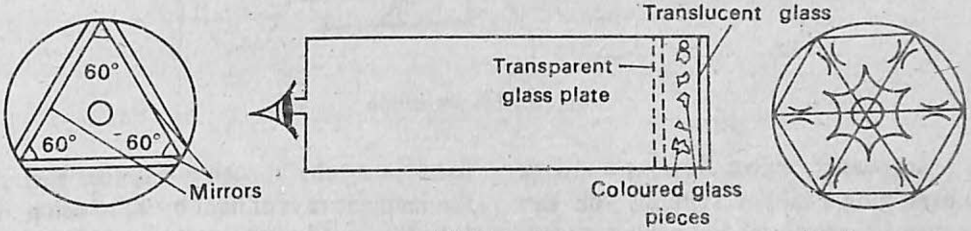
Fig. 10.9

Increase the angle between the mirrors to 90°; the number of image will reduce to three. Decrease the angle to 60° and the number of images will increase to five. If the mirrors are at an angle of 50° the number of images is eight.

Two mirrors inclined to each other at 60° form five images. These five images and the object are all equidistant from the point P and therefore lie on a circle with P as the centre of the circle.

10.6 Kaleidoscope

A kaleidoscope is an interesting toy which makes use of multiple reflections by plane mirrors held at 60° inclination. Three plane mirror strips of equal width and length are held tight inside a cardboard tube so that they are at 60° with one another (Fig. 10.10a). One side of the tube is blocked by coloured pieces of glass held between a transparent and a translucent glass plate, while the other end is blocked by a disc with a small hole to look inside (Fig. 10.10b). When we view through the tube against a bright background, the glass pieces and their images form beautiful coloured patterns which change into innumerable designs as we rotate the tube (Fig. 10.10c).



(a) Front view (b) Side view (c) A pattern

Fig. 10.10 Kaleidoscope construction and view

Experiment 7. Hold two plane mirrors roughly parallel to each other and place a pen cap or a chalk stick between the two. You will find a very large number of images formed in both mirrors due to multiple reflections. The ray diagram (Fig. 10.11) shows how the image I_3 of source S is seen by double reflection. For all practical purposes I_3 is the image of I_1 and is formed as much behind mirror M_2 as I_1 is in front of the mirror. Thereby a series of images result. However, such images become less bright because of absorption of light at successive reflections. Barber shops often have mirrors facing each other fixed on opposite walls. You can then see innumerable images of yourself in the mirrors.

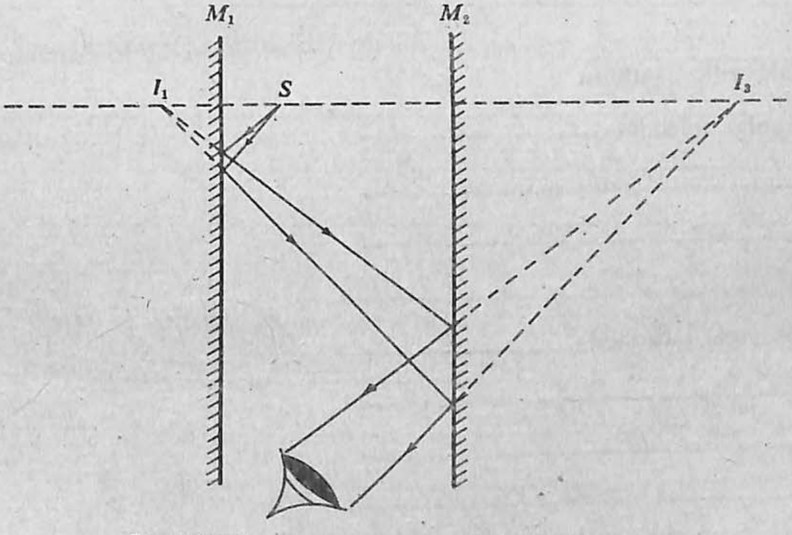


Fig. 10.11 Images formed by parallel mirrors

10.7 Periscope

If you stand in sunlight with a mirror in your

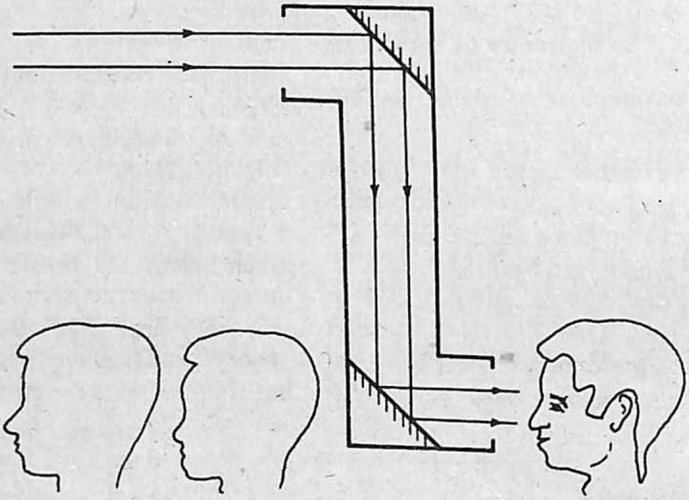


Fig. 10.12 A periscope

hand, you can easily reflect light into a dark room. By arranging a mirror suitably you can also see another person who is behind a wall. Similarly by arranging two mirrors suitably it is possible to see over people's heads (Fig. 10.12). Such an instrument is called a **periscope.** It contains two plane mirrors parallel to each other fixed in a tube in such a way that each deflects the incident rays of light by 90°. Such periscopes are also used by soldiers in trenches. Submarine periscopes which are used to observe ships on the surface of the sea when the submarine is underwater are actually more complicated but essentially work on the same principle.

EXERCISES

1. Explain with diagrams.

(i) Regular reflection. ______________________

____

____

____

(ii) Irregular reflection. ______________________

____

____

____

____

2. State the laws of reflection.

3. What is the difference between the following?

(i) Real image and virtual image.

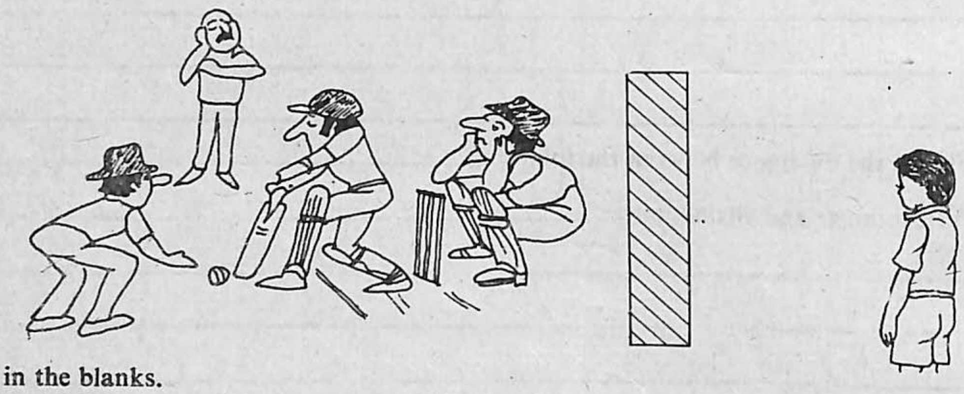
(ii) Incident ray and reflected ray.

4. If you look into a still pond of water you can see your image. Is this a real or a virtual image? Give reasons for your answer.

5. What are the properties of the image formed by a plane mirror?

6. What is a kaleidoscope? On what principle does it work?

7. The figure shows a child wanting to watch a cricket match on the other side of a wall. Which optical instrument can help him? Draw the instrument in the figure and show the path of light.



8. Fill in the blanks.

(i) Irregular reflection occurs because of the ____________ of the surface on which the light falls.

(ii) The point where the incident ray meets the mirror is called the point of ________

(iii) A line perpendicular to the mirror at the point of incidence is called the ________ The angle between this line and the incident ray is the angle of ____________

(iv) If you write with your right hand your image writes with its left hand. The image is ____________ ____________.

(v) Two mirrors inclined at an angle of 60° make ______ images.

(vi) Two mirrors placed parallel to each other make ____________ images of an object kept between them.

11

Refraction of Light

We have seen earlier that light travels in straight lines through air. When obstructed by various objects, it is absorbed, reflected back or transmitted through the object. When a beam or a ray of light passes through a transparent material, such as glass or water, what path does it take?

Experiment 1. Adjust the light box, with a narrow slit in front of it, on a white sheet of paper so that a narrow and bright beam of light is obtained along the paper. Darken the room and hold a rectangular glass trough filled with water in the path of the beam. Add to the water a few drops of milk or preferable a pinch of a chemical called 'fluorescein'. Look at the trough from the top.

You will notice that the beam bends away from its path as it enters the container. However, it follows a straight-line path in the water (Fig. 11.1). *This bending of light as it goes from one transparent medium to another is called* **refraction.** You will notice that the light is refracted a second time as it comes out of the container. Bending by refraction takes place at the two surfaces of separation. There is, however, no change of direction during refraction when the light is incident **normally** (i.e. in a direction perpendicular to the surface) on the surface.

11.1 Effects of Refraction at Plane Surfaces

Light rays suffer change of direction while

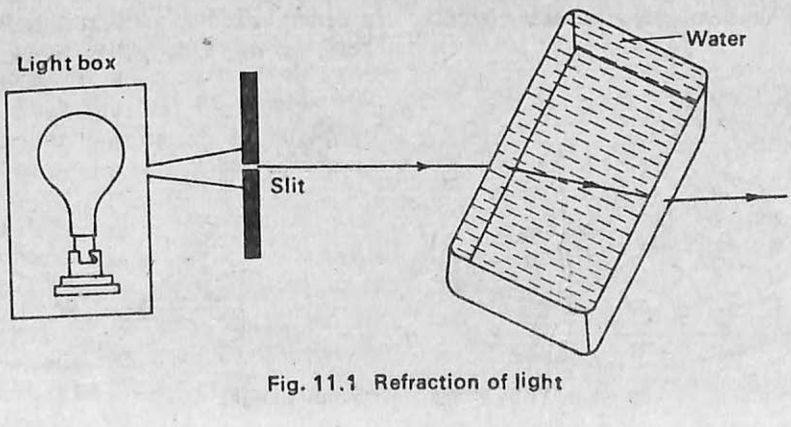


Fig. 11.1 Refraction of light

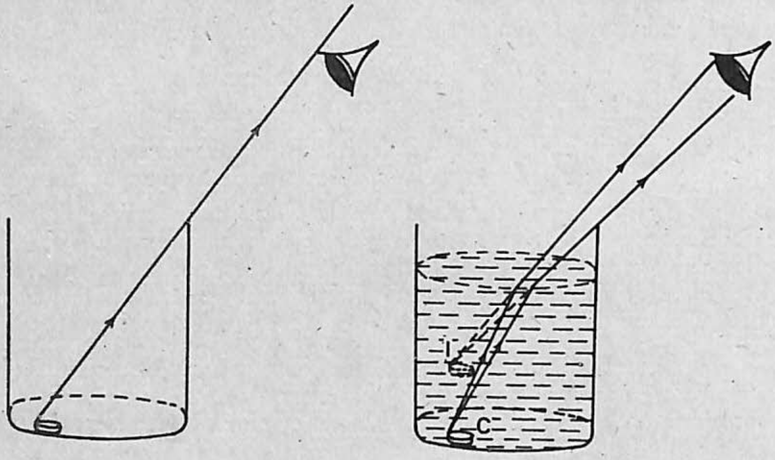


Fig. 11.2 Effect of refraction of light

going from one medium into another. Because of this it appears to us that objects, when viewed through transparent materials, are in different positions than where they actually are. In other words we see the images of these objects.

Experiment 2. Take on opaque container and place a coin at its bottom. Now position yourself such that the coin is not visible, and is just obstructed by the container (Fig. 11.2). Now ask someone to gradually fill water in the container without disturbing the coin. You will observe that as the water level rises, the coin appears in sight.

As Fig. 11.2 shows, light from the coin is refracted as it comes out of the water and reaches our eyes; as a result the rays appear to come from an image *I* of the coin. The coin at *C* appears to be at *I* giving us the impression that the water is shallower than what it actually is.

Experiment 3. Fill a glass trough with water and dip a rod in it obliquely (i.e. not perpendicular to the surface of water). When you look at the ruler from the side through the trough, or from the top, it appears to be bent at the surface of water (Fig. 11.3).

Rays of light coming from the various points of the dipped part of the rod refract as they emerge from water into air. Thus light from each point on the dipped part of the rod has a corresponding image point. The rod therefore appears bent at the surface to our eyes.

11.2 Refraction through Glass Block

Experiment 4. Place a rectangular glass block on a white sheet of paper; trace its outline with a pencil. Fix two vertical pins *P* and *Q* as markers on one side of the block so that the line

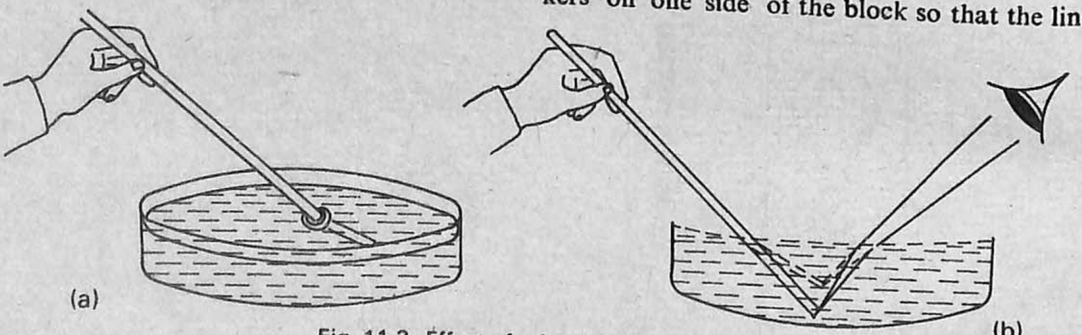

(a)
(b)

Fig. 11.3 Effect of refraction of light

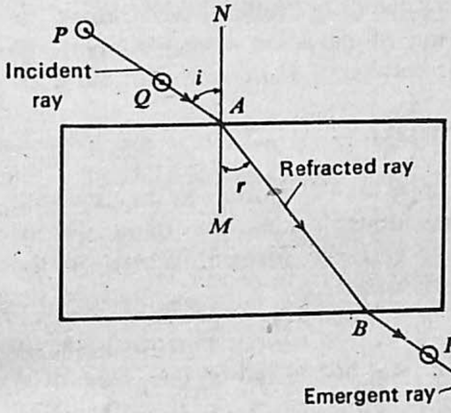


Fig. 11.4 Refraction through a glass block

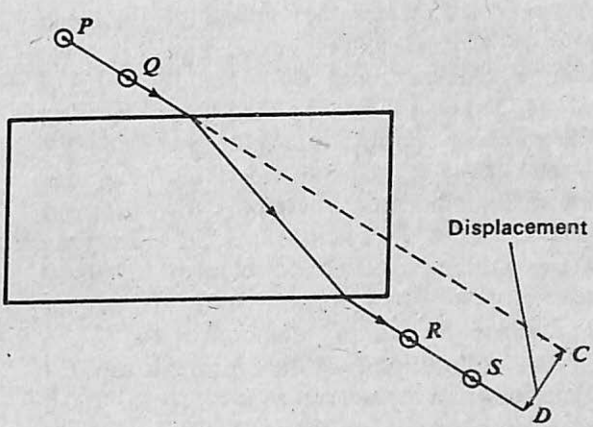


Fig. 11.5 Displacement of light by a glass slab

PQ becomes a ray incident on the glass block. Remove the glass block, draw line *PQ* and a normal *MN* at the point *A* on which the ray is incident. It is desirable that the ∠*NAQ* which is marked as the **angle of incidence** ***i***, is not too small. Now replace the glass block properly along the outline.

Look from the other side and fix pins *R* and *S* as markers such that they are in line with the images of pins *P* and *Q as seen through the block*. Remove the block, produce *RS* to meet the outline of the block at *B*, and mark on it the direction. This line is called the **emergent ray**. The ray of light entered in the block at *A* and came out at *B*. It could be assumed that light travelled from *A* to *B* in a straight line; hence, join points *A* and *B* to obtain a straight line and mark the direction on it. This is called the **refracted ray**.

Now measure the angle of incidence *i*, and the **angle of refraction** ***r***. You will notice that ∠*r* is less than ∠*i*. This shows that *when light enters a denser medium, it is refracted towards the normal*. At *B*, when the ray *AB* emerges out into a rarer medium, the ray *RS* is seen to bend away from the normal.

Displacement

Now produce line *PQ* upto *C*; you will notice that this line is parallel to the emergent ray. While passing through the glass block, the ray got displaced from its original path but remained parallel to it. The distance *CD* (Fig. 11.5) between the incident ray produced and the emergent ray is called the **lateral displacement**.

Repeat the experiment with a glass block of greater thickness *t*, and with different angles of incidence *i*. You will find that the displacement increases with increase of *t* and *i*, but in each case the emergent ray is parallel to the incident ray. When the incident ray is normal on the glass block, i.e. when the angle of incidence is zero, the ray passes straight through the block without displacement.

11.3 Refraction through Prism

Let us study the path of a ray of light through glass when the two refracting surfaces are not themselves parallel to each other. For this purpose, a triangular glass block called a **prism** is taken; faces *XY* and *XZ* are the two refracting surfaces inclined to each other, while the face *YZ* is called the **base** of the prism (Fig. 11.6).

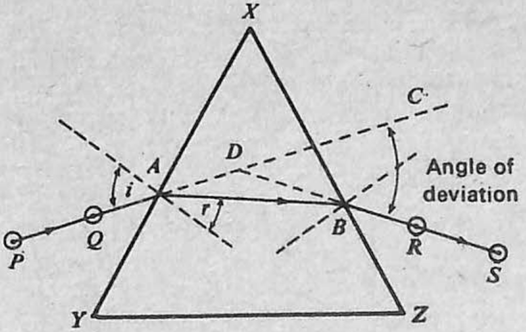


Fig. 11.6 Refraction through a prism

Experiment 5. Draw the outline of the prism on a white sheet, fix two pins *P* and *Q* to form the incident ray, and draw the normal at *A* where the ray is incident on the face *XY*. With the prism in position, look from the side *XZ* towards the prism and fix pins *R* and *S* in line with images of *P* and *Q*. Remove the prism and pins, and draw the emergent ray *SR* to meet the prism outline at *B*. Join *AB* to form the refracted ray through the prism. Mark arrowheads to indicate the path of light from *P* and *S*.

You will notice that the incident ray *PA* bends towards the normal as it enters the glass; as expected, $\angle r$ is less than $\angle i$. When the light from the prism emerges into air at *B*, the emergent ray *RS* bends away from the normal drawn at *B*.

You will observe that if *PQ* is produced to *C*, the emergent ray *RS* is not parallel to it. If *SR* is produced backwards to *PC* at a point *D*, the $\angle CDS$ can be measured. This angle between the incident ray and the emergent ray is called **the angle of deviation.**

The observations of these experiments can now be summed up in the form of the following rules, which would help to understand the phenomenon of refraction.

(a) A ray of light going from a rarer into a denser medium bends towards the normal; the angle of refraction is less than the angle of incidence in this case.

(b) A ray of light emerging from a denser medium into a rarer medium bends away from the normal; in such a case, the angle of emergence is more than the internal angle of incidence.

(c) When the incident ray is normal to the second medium, it is transmitted without change of direction; the angle of incidence and the angle of refraction are both zero.

(d) In case of parallel refracting surfaces (as in a glass slab) the incident and emergent rays are parallel to each other; the ray undergoes displacement without deviation.

(e) In case the two refracting surfaces are not parallel (as in a prism), the incident and emergent rays are not parallel to each other; the ray suffers deviation. The amount of deviation depends upon the angle between the two refracting surfaces.

11.4 Dispersion

You must have seen a rainbow in the sky with its various colours during the rainy season. How is the rainbow formed? Where do the colours come from?

Experiment 6. Allow a very narrow beam of light from a light box to fall on one face of a prism. Hold a white screen on the other side so that light emerging out of the other face falls on it (Fig. 11.7). You will see that the light has spread out into many colours on the screen. This separation of light into its various components is called **dispersion**. The spread out patch of light on the screen is called a **spectrum.**

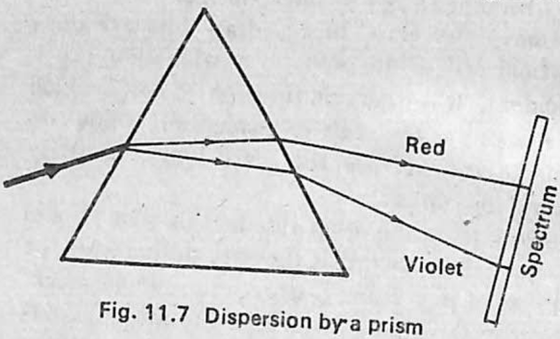


Fig. 11.7 Dispersion by a prism

The order of colours is the same as that seen in a rainbow, with the red bending least and the violet most. A rainbow is formed when rays of the Sun refract through water particles suspended in air. The major rainbow colours which you may be able to detect are violet, blue, green yellow and red, in that order. Actually the rainbow, as well as the spectrum formed by you, have seven colours—violet, indigo, blue, green, yellow, orange and red. For the names and the order of colours you can remember the word VIBGYOR formed by using the first letter of each colour. Thus, when a ray of light is refracted through a prism, it not only suffers deviation but also dispersion. The deviation is least for red and most for violet, in the case of any particular prism.

It is possible to recombine the colours by the following method.

Experiment 7. Remove the screen and place a second prism with base upwards in the path of light. The white screen is placed in the path of the light transmitted through the second prism. The arrangement will need some adjustment. You will obtain on the screen a single beam of light without dispersion (Fig. 11.8).

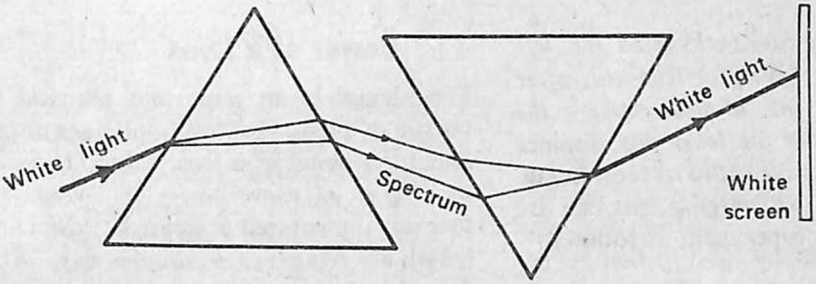


Fig. 11.8 Recombining the colours of the spectrum

The emergent light which is a combination of all the rainbow spectrum colours is called **white light**. (Light itself is invisible; yet the term 'white light' is in common usage. You should therefore clearly understand the meaning of this term)

11.5 Colour of Objects

When light falls on an opaque object, part of it may be absorbed and the rest reflected; the reflected part gives the object its characteristic colour. Thus, incident light is *selectively absorbed* by an object, and the object appears to be of a colour depending upon the light that reaches our eyes. For example when sunlight alone falls on a green leaf all the light is absorbed except green, hence the leaf will appear green.

11.6 Lenses

So far we have studied examples of refraction where the surface of separation was plane. The most common example of refraction which is put to practical use is at spherical surfaces when we use a **lens**. *A lens is a refracting medium with at least one surface spherical.* Although there are many shapes (Fig. 11.9) and sizes of lenses in use, essentially these are of two types: **diverging and converging.**

A diverging lens can be recognised by feel of the hand. As shown in Fig. 11.9a the lens is thin in the middle and thicker at the edges. If you look through a diverging lens, all objects will appear smaller.

The function of a diverging lens is to spread outwards (diverge) an incident beam of light.

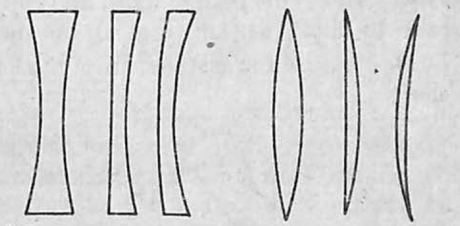
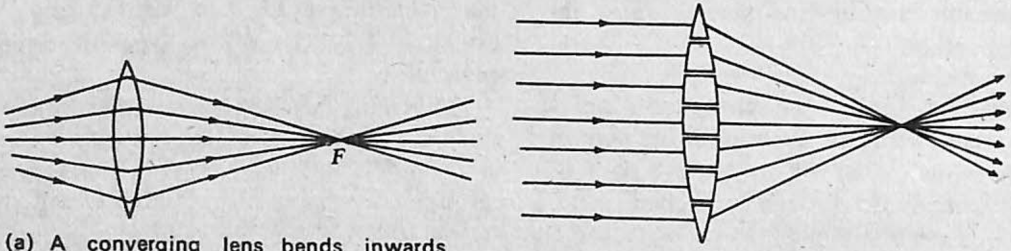


Fig. 11.9 Lenses

Whichever of the three types of converging lenses you take, it can be recognised by the feel of the hand. A converging lens is thick in the middle and becomes thinner at the edges. The property of a converging lens is to bend inwards (converge) light rays as they pass through the lens. The converging lens can bring several parallel rays to one point after refraction (Fig. 11.10a). This action can be understood if we imagine a converging lens to be made up of several sections of triangular prisms, with a thin glass slab in the middle (Fig. 11.10b).

The point F is called the **principle focus**, or simply the **focus**, of the converging lens.

Light could be incident on a lens on any of the two surfaces but the property of convergence



(a) A converging lens bends inwards (converges) light rays

(b) The action of a converging lens

Fig. 11.10

does not alter. *Parallel rays incident on the left or right surface of the converging lens will, after refraction through the lens, always converge the same distance away from the lens; this distance from the lens of the focus is called its* **focal length.**

The focal length of a converging lens can be found out by a simple experiment as follows.

Experiment 8. Place a white sheet of paper facing the Sun. Now hold a converging lens (magnifying glass) in the path of light, and adjust its distance, to obtain a bright spot on the sheet (Fig. 11.11). Measure the distance from the lens to the sheet.

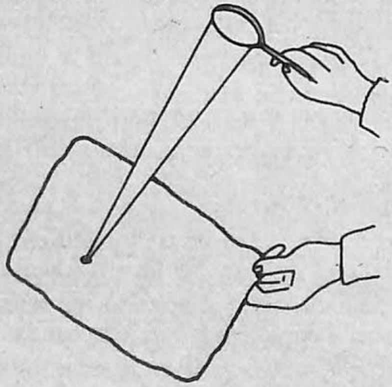


Fig. 11.11 Finding the focal length of a converging lens

Usually rays coming from a very distant object, such as the Sun, are considered parallel to each other. The bright spot formed is therefore at the focus of the lens; the distance from this spot to the lens gives us the approximate focal length of the lens.

11.7 Power of a Lens

Focal length is an important physical characteristic of a lens. However, opticians usually talk about the **power** of a lens. *Power is defined as the degree of convergence or divergence of a lens and is measured in* **dioptres.** Power and focal length are related in a simple way. When the focal length is expressed in centimetres, and the power in dioptres:

$$\text{Power} = \frac{100}{\text{Focal length}}$$

Thus, in the above experiment, if the focal length of the lens is 13.2 cm,

$$\text{Power} = \frac{100}{13.2} = +7.5\ \text{D}$$

If the power of a lens is given as $+0.5$ D, we can find out its focal length by rewriting the above equation:

$$\text{Focal length} = \frac{100}{\text{Power}} = \frac{100}{0.5} = 200\ \text{cm}$$

If power of a lens is given as -0.5 D, its focal length will be -200 cm. The negative sign indicates that it is a diverging lens. A diverging lens has a negative power and a negative focal length.

11.8 Lens Camera

The box camera is similar in construction to a pin-hole camera, except that there is a converging lens instead of the hole and the screen is a light-sensitive film. When the shutter S is open, light from a distant object passes through the lens and forms an inverted and diminished image on the film E (Fig. 11.12). As long as the object

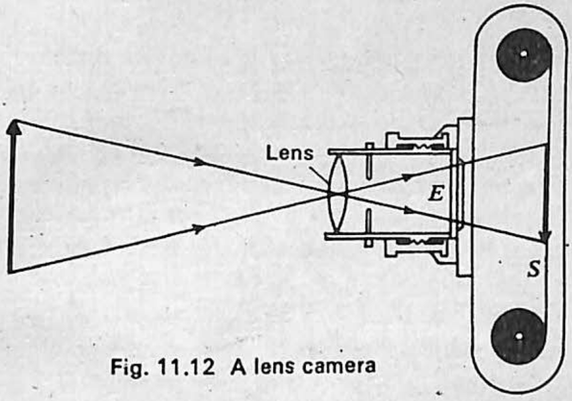


Fig. 11.12 A lens camera

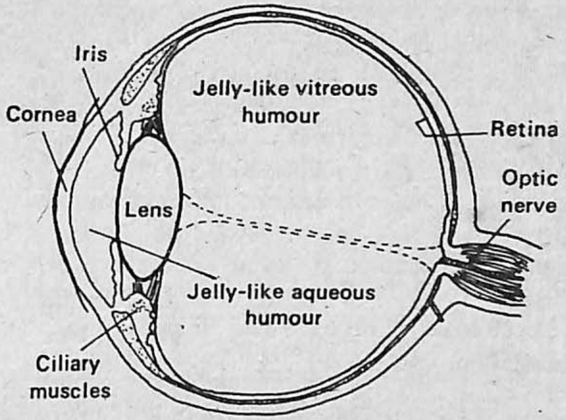


Fig. 11.13 The human eye

is beyond about 4 metres, the image-lens distance is almost constant, which is slightly more than the focal length of the lens. When the camera is so adjusted, with object not too close to the camera, the image formed on the film is reasonably sharp. The large lens surface allows plenty of light to enter the box, thus forming a bright image. It also enables us to adjust the time of exposure to a fraction of a second so that a sharp image of even a moving object can be formed.

In good cameras an **aperture** arrangement (opening of lens surface) and the **timing device** (shutter speed) together enable a controlled amount of light to fall on the film. The film thus exposed to light is then processed and a print of the image obtained. In such cameras, when the object is closer, the image-lens distance can be increased to form a sharp image. This is achieved by moving the lens away from the film, employing a screwing arrangement.

11.9 The Human Eye

The eye resembles a lens camera in many ways but there are some important differences also. In its action and performance, the eye is a very perfect and an automatic optical instrument.

The **lens** of the eye is made of a jelly-like material; it converges light to form a real, inverted and diminished image of an object on the light-sensitive screen called **retina** (Fig. 11.13). The **optic nerve** carries the impressions on the retina to the brain where the image is made erect and interpreted.

The coloured circular portion in front of the eye lens is called the **iris**. By muscular action it adjusts the aperture of the lens, thus controlling the amount of light entering the eye. The central opening through which light enters the eye is called **pupil**. From outside, it appears back.

Experiment 9. Hold a mirror in front of you and look into your eyes. Locate the iris and the pupil in the middle of it. Now shine a torch on one of the eyeballs and notice how the pupil width changes. You will observe that the pupil area becomes less and thus reduces the light entering the eye; this is essential to avoid damage to the retina. Now remove the torch and observe the increase in width of the pupil. This action of the iris in adjusting the aperture is almost automatic (involuntary).

An important difference between a camera and an eye is the arrangement for obtaining a clear image on the screen. In a camera, when the object comes closer the image-lens distance is increased; hence, the lens has to be moved forward to bring the image on the film. However, when a closer object is to be clearly seen by the eye, the eye lens increases in power, thus effectively keeping the image-lens distance constant. The power of the eye lens is changed by making the lens thick (more power) or thin (less power); this is accomplished by stretching or relaxing the **ciliary muscles**. This involuntary action of ciliary muscles, which is called **accommodation of the eye**, suitably alters the power of the eye lens to obtain a sharp image on the retina when the object distance is changed.

When a very far off object such as the Moon and stars are viewed, the retina-lens distance is equal to the focal length of the lens. In this condition the eye is most relaxed and the lens has least power. A closer object would require more power of the lens, increasing strain on the eye. The closest distance that any object can be held to be seen clearly is called the **near point** of the eye. In this condition the power of the eye lens is maximum.

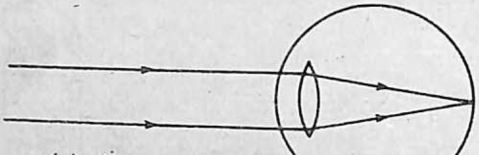
Experiment 10. Hold this book in front of you and look at the words. Move the book closer to your eyes; keep your eyes fixed on the words. You will find that the words look blurred. Now gradually take the book away from your eyes and stop when you see the words clearly again. This is the approximate near point distance of your eye. For normal eyesight, the near point distance is about 20 to 25 cm. Children have a closer near point.

11.10 Defects of Vision

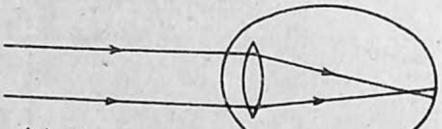
We see lots of people around us wearing spectacles; some wear coloured glasses, whereas others wear them to correct defects of vision. Let us consider the cause of some defects and how spectacle lenses are used to correct them.

Myopia or Short Sight

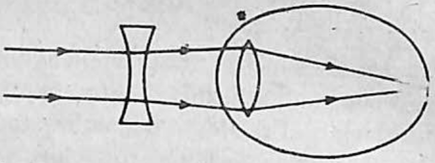
This is a defect of the eye when a distant object cannot be seen clearly. It occurs when the eyeball is elongated so that the retina-lens distance is increased. For the normal eye, an object at great distance forms a clear image on the retina when the eye lens has least power (Fig. 11.14a). In a myopic eye the same object will form a sharp image between the eye lens and retina (Fig. 11.14b); the image on the retina will therefore be blurred. In order to correct such a defect, a negative power (diverging) lens is held in front of the eye; in effect, the spectacle lens and eye lens combination reduces the convergence of the incoming rays of light. Thus by using a suitable divergent lens in front of the eye, the final image can be brought on the retina (Fig. 11.14c).



(a) A normal eye



(b) A myopic eye

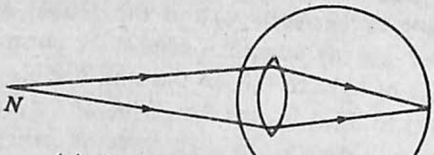


(c) Myopia corrected by divergent lens

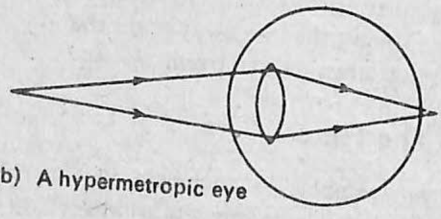
Fig. 11.14

Hypermetropia or Long Sight

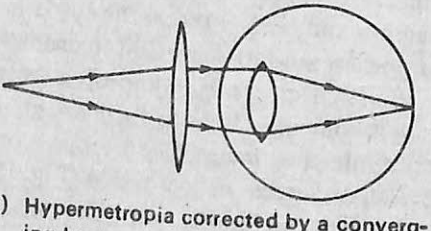
This is a defect of the eye when near objects



(a) A normal eye



(b) A hypermetropic eye



(c) Hypermetropia corrected by a converging lens.

Fig. 11.15

cannot be seen clearly. It is caused by shortening of the eyeball so that the retina-lens distance becomes smaller. For the normal eye, an object at near point *N*, forms a clear image on the retina when the eye lens has maximum power (Fig. 11.15a). The same object will form a blurred image on the retina in a hypermetropic eye, because rays from the object would converge to a point behind the retina (Fig. 11.15b). In order to correct such a defect, a convergent lens is held in front of the eye lens; in effect, the convergence of incoming rays of light is more due to the combination of spectacle and eye lenses. Thus, using a suitable converging lens in front of the eye, the final image can be brought on the retina (Fig. 11.15c).

11.11 Simple Microscope

A single converging lens used as a magnifying glass is also called a simple microscope. It is used to view small objects in greater detail.

Experiment 11. Place a magnifying glass on this book. Now lift it and gradually move it away from the book. You will notice that the letters appear enlarged. What you see through the lens is an image of the letters. Hold the lens on a graph paper and adjust it again. The squares appear to be bigger (Fig. 11.16).

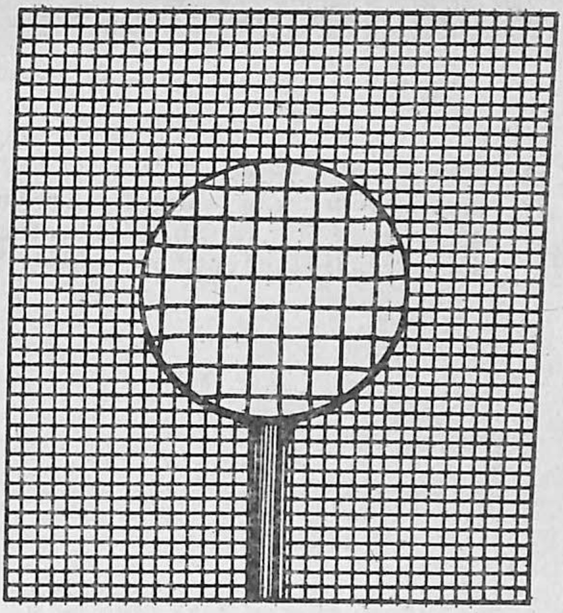


Fig. 11.16 A simple microscope

EXERCISES

1. (i) What is refraction? ____________________

____

____

(ii) Where does it take place? ____________________

____

2. (i) Draw a clear ray diagram and explain how a ruler dipped obliquely in water appears to be bent. ____________________

____

____

____

(ii) Why does the bending disappear when the ruler is held normally dipped in water? ______

______

______

3. Draw a clear ray diagram showing a ray of light incident on a rectangular glass block and emerging from the opposite face. Show on the diagram the angle of incidence, the refracted ray, the angle of refraction, the displacement which has taken place, and the partial reflection occurring at the point of incidence.

4. (i) What are the factors on which lateral displacement depends? ______

______

______

(ii) Under what condition is lateral displacement zero? ______

______

5. (i) With the help of a clear ray diagram show how deviation takes place during refraction in a triangular prism?

(ii) On what factors does deviation depend?

______

______

______ ______

6. (i) Name the colours in the spectrum of sunlight formed by a prism. ______

______

(ii) Which colour has maximum and which has minimum deviation?

(iii) Why do you normally not get a spectrum from a very broad beam of white light refracting through a prism?

7. What are the main differences between a converging and a diverging lens

(i) in their construction?

(ii) in their properties?

8. Explain the following terms as applied to a converging lens.

(i) Focus

(ii) Principal axis

(iii) Optical centre

9. Describe one method of determining the focal length of a lens.

10. (i) What is meant by power of a lens. Define a dioptre.

(ii) The focal length of a converging lens is 30 cm. Calculate its power.

(iii) What would be the focal length of a lens whose power is —4D? What type of lens is it?

11. Compare the action of the human eye to that of a lens camera with regard to

(i) the method of 'focusing' near and distant objects.

(ii) the method of controlling the amount of light which enters the instrument.

12. (i) What is hypermetropia? What is its cause?

(ii) How can it be corrected? Explain with a diagram.

13. (i) What happens to a parallel beam of light as it passes into a myopic eye? ____________

____

____

____

(ii) How can the beam be brought to focus on the retina? ____________

____

____

14. Fill in the blanks.

(i) A ray of light going from a rarer medium to denser medium bends ____________ the normal.

(ii) A ray of light going from a rarer medium to a denser medium does not undergo refraction if $\angle i =$ ____________.

(iii) The separation of light into its various components is called ____________.

(iv) A blue flower absorbs all light except ____________.

(v) A blue flower viewed in red light would appear ____________.

(vi) A converging lens is ____________(thicker/thinner) in the middle than at the edges.

(vii) In a camera a ____________(real/virtual) image is formed on the film.

(viii) An object kept closer to the eye than the ____________ ____________ cannot be seen clearly.

(ix) The automatic adjustment of the eye lens focal length to view objects is called ____________ of the eye.

(x) In a simple microscope the image formed is ____________(virtual/real).

12

Sound and Waves

Seeing is one of the best ways of finding out about things that go on around us; hearing is another. We feel thrilled listening to an exponent of music play on his sitar or sarod, but get irritated at the rattling of windows due to sonic booms or the thunder of clouds. Loudspeakers and vehicles make us unpleasantly aware of sounds in cities, while the chirping of birds and the gentle murmur of a stream in a forest or mountain soothen our nerves and give joy to us. We hear with our ears the sounds produced by all these sources. How is sound produced? How does it reach our ears? What makes a sound unpleasant or melodious?

12.1 Vibrations and Pitch

Experiment 1. Pluck the string of a musical instrument and watch how it moves. A paper rider placed on the string will jump off.

Strike a **tuning fork** against a soft pad, such as a rubber bung or the rubber sole of a shoe. Observe closely the **prongs** of the tuning fork; they appear hazy. Feel them with your fingers. Can you feel them vibrating?

Hold the tuning fork over water in a wide trough with one prong just touching the water surface (Fig. 12.1). You will see ripples produced on the water surface spreading out from the point where you touch the prong.

Sound is generated by the **vibration** *of objects.* Every sound that you hear can be traced back to some source that vibrates. Vibration is the name given to the *to and fro movement* of an object.

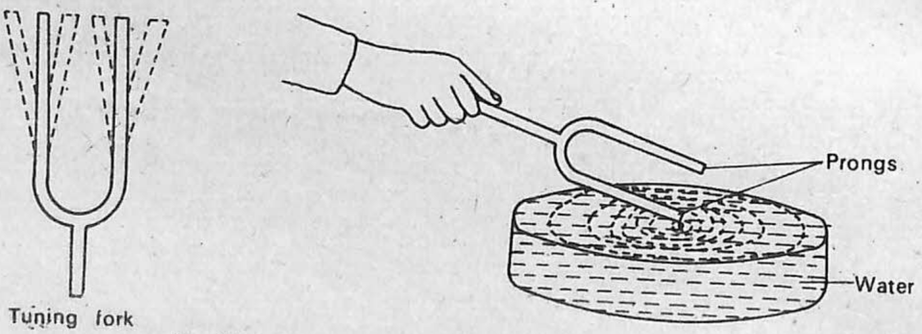


Fig. 12.1 Sound is produced by vibrations

Pitch

Many sounding objects vibrate at a constant rate; they then produce a steady **note.** *The number of vibrations that a source of sound makes every second is its* **frequency;** *the frequency of any note is its rate of vibration.* The higher the frequency the shriller is the sound.

Pitch is the shrillness or flatness of the sound heard and depends upon the frequency. More the frequency higher the pitch. Thus, a tuning fork is often marked to indicate its constant pitch. If its pitch is 320 **hertz,** it means that the prongs make to and fro vibrations 320 times every second. Any sounding object, vibrating with a frequency of 320 hertz will appear to have the same note. Musicians tune instruments to match the frequency by listening to the note they produce.

Experiment 2. Firmly clamp a hacksaw blade (a stiff metal strip would do) on to a table with the help of a G-clamp. About 15 cm of the blade should project out of the edge of the table (Fig. 12.2). Allow the strip to vibrate by pressing down the free end of the blade. You will hear a note of constant pitch. Allow the sound to fade away; the pitch will not change.

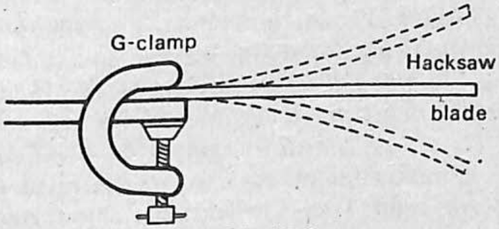


Fig. 12.2

Stretch a rubber band tightly between two supports. Pull it sideways with a finger and let it go. You will hear a note as it vibrates. Now pluck it harder and listen to the note. The loudness will be more but the pitch remains unchanged. Thus, *pitch of a note does not depend upon its loudness.*

Siren

Experiment 3. An example of change of pitch with frequency is the sound produced by a siren. A siren consists of a rotating disc with a number of equally spaced holes along a circle. Air is blown through a jet along the circle (Fig. 12.3). As the disc rotates, air escapes through the holes when they come in front of the jet; when a hole is not in front of the jet, the air is blocked. Thus vibrations are created in air in front of the jet.

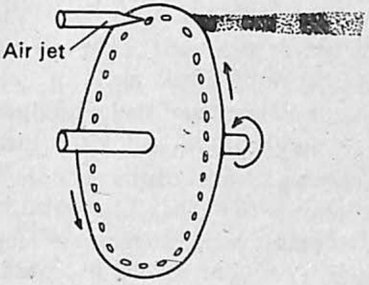


Fig. 12.3 A siren

When the disc is rotated at constant speed, a constant note is heard. With increase of speed of the disc, the rate of vibration of air increases and the pitch is raised. If the disc speed is not constant, a changing pitch will be heard; this is what happens when the air raid siren is sounded.

Oscillations

Experiment 4. Tie a lump of metal, such as a spherical *bob* or a 50 g mass, to a string, and suspend it from a retort stand. You have now set up a pendulum. Pull the bob to one side and

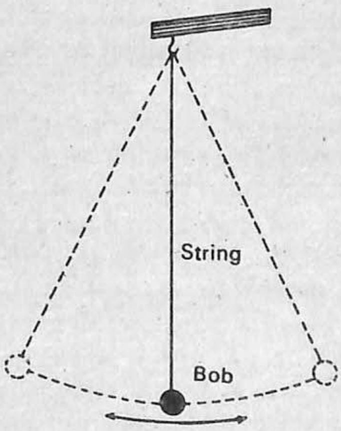


Fig. 12.4 Oscillations of a pendulum

release it; the pendulum makes to and fro movements. Each complete to and fro movement (Fig. 12.4) is called an **oscillation.** Time the pendulum for 10 oscillations; hence, calculate the **time period** T for one oscillation. Increase the amplitude of oscillation and record the time period again. Take a heavier mass and repeat the experiment. You will observe that the time period does not change with change of mass of bob or with change of amplitude.

Now change the length of the pendulum and repeat the experiment to calculate the time period for varying lengths of the pendulum. The experiment shows that the time period of a pendulum increases with increase of length of the pendulum. Pendulum clocks are based upon this principle to measure time.

12.2 Types of Sounds

When sounding objects vibrate at many different rates and their pitch is constantly varying, they emit what is known as **noise**. For example, when we bang our fist on a table, the sound we hear is not musical because the vibration rate is rapidly changing. *Noise is a jumble of varying notes without any simple relationship between them.* The instruments in an orchestra are tuned so that the notes produced together develop a pattern which is pleasing to the ear. Such sound is known as **music**.

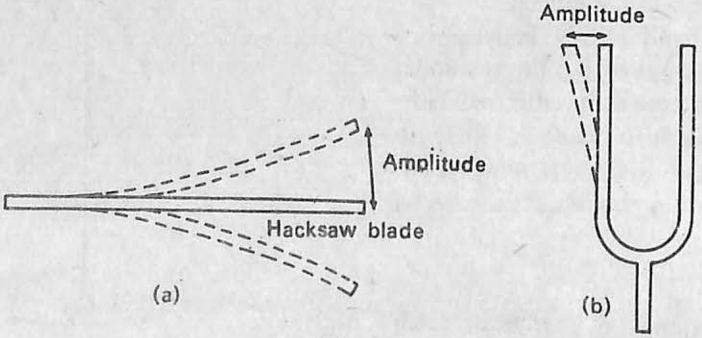
The human ears are sensitive to sounds with frequencies ranging between 20 and 20,000 Hz approximately. These limits are reduced with age and with ear defects. Sounds which have frequencies above our **audible** limit are called **ultrasonic** sounds; those which have frequency below our audible limit are called **infrasonic.** For example, an oscillating pendulum produces waves in air just like any other vibrating object, but out ears cannot hear any sound as the frequency of vibration is much lower than 20 Hz.

Bats are known to produce sounds of about 50,000 Hz. Some fish communicate by ultrasonic sounds, and this knowledge is used in some places to produce ultrasonic sounds electronically, to attract fish and catch them in nets.

12.3 Loudness

A sounding object has first to be given energy to make it vibrate. As the sound energy spreads around, mechanical energy in the source becomes less; its vibrations are seen to fade out. The sound heard from a tuning fork or a vibrating string becomes weak as time passes.

Experiment 5. Clamp the hacksaw blade as described in Experiment 2 and make it vibrate. Observe the extent of the to and fro swing of the blade and listen to the note. You will notice that the swing becomes less as the sound fades out. *The maximum distance from the rest (undisturbed) position through which a vibrating object moves is called its* **amplitude.** The extent of vibration (amplitude) is a measure of the energy emitted by the vibrating object. Hence the amplitude determines the loudness of the sound. The greater the amplitude, the greater is the energy transmitted by the vibrating body and the louder is the sound it produces. The energy also depends upon how massive the object



(a) (b)

Fig. 12.5

is; a light (less massive) object will emit less energy.

In the vibrating object there is a continuous interconversion of energy from kinetic to elastic and vice-versa.

12.4 Propagation of Sound

The sound from a source reaches our ears through the air. What would happen if the air were absent?

Experiment 6. Suspend an electric bell inside a bell-jar, and take out wires leading to it through a tight cork. Place it on a flat circular disc with a hole in the middle which is connected to an exhaust pump. The edges of the jar are greased so that its contact with the disc is air-tight (Fig. 12.6). Now connect cells and a switch in series with the bell and complete the circuit. Notice the movement of the hammer and listen to the sound, as current passes through the bell.

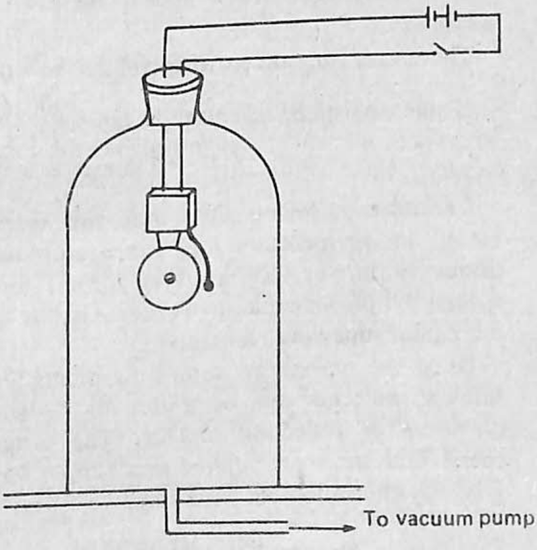


Fig. 12.6 Sound requires a medium to travel

Now gradually remove air from the bell-jar by means of the exhaust pump. You will observe that sound from the bell becomes weaker, and ultimately almost inaudible, but the hammer is seen to vibrate and strike the gong continuously. Now release air again into the bell-jar by disconnecting the pump; the sound is again heard clearly.

Experiment 7. Place a watch under a pillow. When you sleep with one ear pressed against the pillow, you can distinctly hear the ticks. If you scratch one end of a wooden plank or rod, the sound produced can be clearly heard if an ear is pressed against it at the other end.

These experiments show that sound travels through air, liquids and solids. In the absence of any medium, no sound will be transmitted.

12.5 Reflection

Sound can also be reflected as shown by the following experiment.

Experiment 8. Take a box lined with cotton wool. Place a ticking clock into it. Stand slightly

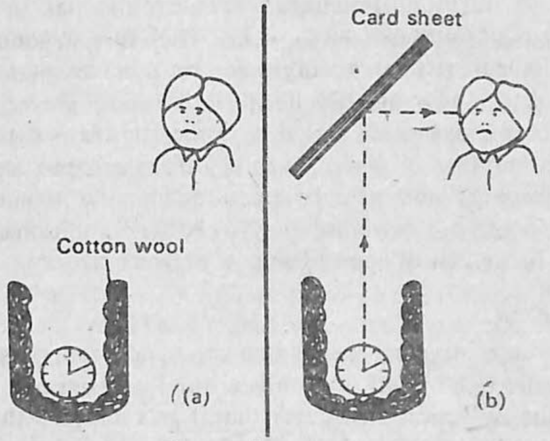


Fig. 12.7 Reflection of sound

away from the box so that the ticking sound is not heard (Fig. 12.7a). Now hold a card sheet above the open end of the box. Gradually tilt the sheet till you hear the sound (Fig. 12.7b).

It is observed that sound is reflected just like light or heat radiations. You can construct a simple **stethescope** using a rubber tubing with a glass funnel fitted at one end (Fig. 12.8). Hold the funnel on a clock and place the other end of the tubing into your ear. You will hear the ticking sound which reaches you after many reflections inside the tubing.

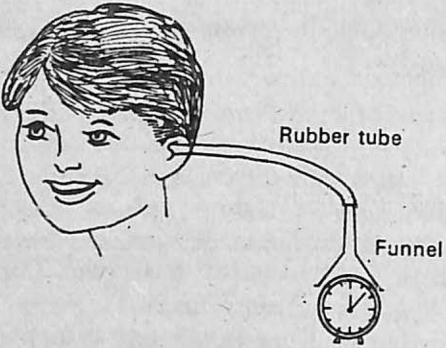


Fig. 12.8 A home made stethescope

In the above experiment, the box was lined with cotton wool to absorb sound. Good auditoriums have absorbants on the wall at the back to stop undue reflections. Curtains, carpets, etc. also absorb sound to a certain extent. Clothes that people wear also make a difference. Generally, musicians prefer that some sound is reflected, but for speeches it is desirable that the sound fades out very quickly. Therefore, in good halls there is an arrangement to remove sound absorbing materials if music is being played. Nowadays sound absorbing materials are used at a number of places, such as offices, aeroplanes, hospitals and factories, to cut down noise so that people can work and stay in better conditions. Too much of sound leads to nervous strain.

Echo

When someone speaks in a room, the sound is reflected by all the walls around us. However, the reflection is so quick that it gets mixed with the original sound. If you stand far from a vertical wall or a cliff and utter a loud sound you can hear a distinct reflection; this is called an **echo**.

12.6 Speed of Sound

When a starter in an athletic event fires a gun, the sound is heard a fraction of a second after the smoke is seen from the finish line of a 100 m race. Spectators watching a game of cricket hear the sound a split second after a batsman makes a stroke. Obviously, sound travels fast enough but not as fast as light does. The echo method can be used to find out the speed of sound.

Experiment 9. Stand about 100 metres away from a tall vertical wall of a building; it is necessary that there should be no other building close by to produce unwanted echoes. Clap your hands once; you will hear an echo after a fraction of a second. The time taken is so small that you cannot measure it accurately. The simple echo method therefore cannot be used to find out the speed of sound.

Now clap with a steady rhythm *periodically*, such that the echo arrives between two successive claps. Once the rate of clapping is adjusted with some practice, record the time for, say, 40 clap-intervals (time between 1st and 41st clap); you will need the help of someone else to record the time.

Let us assume that the time interval between 40 claps is 48 seconds.

Then, time interval between two successive claps $= \frac{48}{40} = 1.2$ s.

In half this time sound goes to the wall and returns.

Therefore, time taken to travel 200 m = 0.6 s.

$$\text{Hence, the speed of sound in air} = \frac{200 \text{ m}}{0.6 \text{ s}}$$

$$= 333 \text{ metres/second}$$

Careful experiments show that the speed of sound in air increases with temperature and is about 340 m/s or 1650 km/h at normal temperature. Jet planes capable of exceeding this speed are called supersonic aircrafts.

Once the speed of sound in a medium is known, the echo can be useful in measuring distances of reflecting objects. The distance, speed and time are related in a simple way as given by the following equation:

$$\text{Speed} = \frac{\text{Distance covered}}{\text{Time taken}}$$

For example, the speed of sound in water is about 1500 metres/second. This information is used to find out the depth of seas at various places to chart the sea bed, by sending sound signals through water from ships floating on the water surface (Fig. 12.9). If an echo is received 4 seconds after the production of sound, then

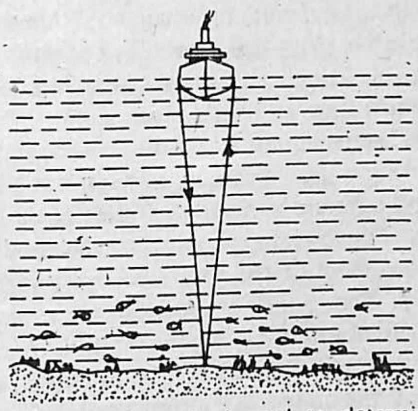


Fig. 12.9 The echo method used to determine the depth of seas

the distance covered both ways by sound is given by:

Distance both ways = speed × time taken
$= 1500 \times 4 = 6000$ metres.

Depth of sea at the place would therefore be 3000 metres.

12.7 Sound Waves

When vibrating objects lose their mechanical energy to the surroundings, it is carried away from the source in all directions. This transfer of energy takes place in the form of **waves.**

Experiment 10. Drop a stone in still water in a pond; you will see circular waves spreading out on the water surface. Thus energy is **propagated** with equal speed in all directions on the surface of water. If there are any dry leaves (or a paper boat floating on the surface, you will notice that they move **up and down** while energy is transferred along the surface; the floating objects themselves do not move in the direction of the wave.

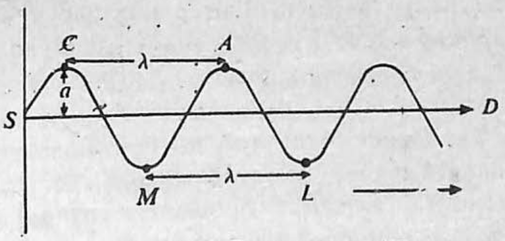


Fig. 12.10 Transverse waves

Figure 12.10 shows a section of the water surface; a vibrating source at S produces a wave which proceeds in the direction SD. The particles of water between the source and D (for example C and M) move up and down, and themselves vibrate, as the wave proceeds along SD. *When particles of a medium vibrate perpendicular to the direction of wave motion, this is called* **transverse wave motion.**

In the diagram, a denotes amplitude, the maximum distance of displacement of the particle C. As the wave proceeds along SD the amplitude of vibrating particles decreases due to gradual spreading and loss of energy in the form of heat.

In a similar fashion, sound produced by a source speads out in the form of waves. The air carries sound energy in the form of waves. A vibrating loudspeaker S, for example, pushes air at regular intervals of time while its cone moves forward. When air in a particular region gets squeezed due to a push, we say that a **compression** is formed. The push is transmitted further away from the source along the compression.

However, as the loudspeaker cone is pulled back, air in front of it gets spread out and a low pressure region is created; this is called a **rarefaction.** A second compression then follows, and so on. The air particles themselves only vibrate forward and backward as the energy is transmitted forward in the form of compresions and rarefactions (Fig. 12.11). *When the particles of a medium vibrate in the same line as the direction of propagation of a wave, this is called a* **longitudinal wave motion.**

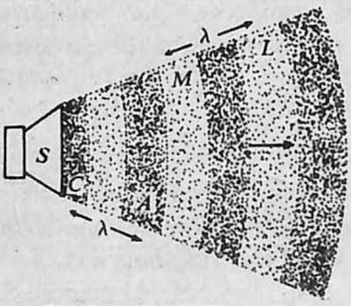


Fig. 12.11 Longitudinal waves

Thus, sound is transmitted away from a source like ripples in air. However, instead of moving up and down (transverse) as in the case of water, air particles vibrate forward and backward (longitudinal). It should be noted that in both cases the particles of the medium do not themselves drift in the direction of wave propagation. Also, if the amplitude of vibration of the source is greater, then the particles of the medium through which the energy is transmitted will vibrate with greater energy.

Wavelength

When a compression C is produced by the loudspeaker cone (Fig. 12.11), the previous compression will have travelled forward to A. Successive compressions proceed forward while the distance between any two adjacent compressions is constant, because the speed is constant. This distance is also equal to the distance between any two adjacent rarefactions, such as ML. This distance is covered by the wave during one complete to and fro movement of the cone. *The distance travelled by a wave in one complete vibration of an energy source is called its* **wavelength**, *and is denoted by* λ (lambda).

In the case of a transverse wave, such as a wave on a water surface, Fig. 12.10 shows the distance CA or ML as equal to one wavelength.

Consider a vibrating object of frequency f whose energy popagates with a wavelength λ. In one vibration, the wave proceeds a distance λ. Hence in one second the wave proceeds a distance $f \times \lambda$ in the forward direction. The speed of this wave is therefore related to frequency and wavelength by the following equation:

$$\underset{(\mathrm{m/s})}{\text{Speed } (V)} = \underset{(\mathrm{Hz})}{\text{Frequency } (f)} \times \underset{(\mathrm{m})}{\text{Wavelength } (\lambda)}$$

For example, if a tuning fork produces a note of frequency 320 Hz, and the speed of sound in air is 340 m/s, the wave will proceed forward with a wavelength

$$= \frac{340\ \mathrm{m/s}}{320\ \mathrm{Hz}} = 1.06\ \mathrm{m} = 106\ \mathrm{cm} \text{ approximately}$$

12.8 Musical Instruments

If a violin, a guitar and a piano are tuned to play the same note, the strings vibrate with the same pitch. Yet, it is possible to identify instruments by listening to the sounds they produce. This difference in sound gives each instrument its distinctive quality. Studies show that most vibrating objects generate not just one pitch but several others which are multiples of the lowest pitch. The lowest note is called the **fundamental** and has most of the sound energy being transmitted. The small proportion of energy, and their distribution, among the multiple frequencies gives a sound its quality. The multiple frequencies of the fundamental are called **harmonics** or **overtones.**

When a sitar player raises the pitch of notes on a string, he presses down with his finger against a partition and this makes the vibrating section of string shorter. He plays on his instrument various tunes by a successive combination of high and low notes as he shortens and lengthens the vibrating section by moving his finger up and down the sitar. Guitar, violin and sarod are other stringed instruments which work in this way.

Experiment 11. Clamp the hacksaw blade again and make it vibrate. Now clamp a shorter length of it and listen to the note it produces. You will observe that the *shorter the length the higher the pitch.*

The pitch of a string can also be raised by tightening the string. At the beginning of a performance, stringed instruments are tuned in this way. The mass of the string also affects its frequency; where high pitch notes are required, the strings used are thin and light (less dense).

Wind instruments have air columns which vibrate just as well as strings. The flute and the shehanai are examples of wind instruments in which holes are opened and closed in order to the change the length of air column that vibrates. Opening a hole has the same effect on an air column as placing a finger on a string: the pitch rises.

The length of air column in a trombone is changed as the side moves in and out. In a trumpet or a bugle, the pressure is changed on the lips to produce different notes.

In a percussion instrument, such as a drum, tabla or mridangam, the stretched skin is made to vibrate by striking it. Loudness is increased by striking the skin harder, and the pitch is increased by stretching it more.

The human voice is employed as a natural musical instrument while singing. While speaking or singing, muscles alter the shape, size and tension of the vocal chords. The vocal chords vibrate as we breathe out and produce sound waves.

Sound is one of the most precious gifts of Nature to man. However, by increasing the noise all around us and causing noise pollution we may gradually lose this gift, as noise pollution can lead to hearing defects besides mental tension.

EXERCISES

1. Give three examples of vibrations in the production of sound. ______

2. Explain the following.

(i) Frequency ______

(ii) Pitch ______

(iii) Hertz ______

3. Explain the difference between the following.

(i) Noise and music. ______

(ii) Ultrasonic and infrasonic. ______

4. (i) What is an echo? ______

(ii) How can the echo method be used to find the depth of a sea? ______

5. (i) How will you show that a medium is necessary for the propagation of sound? ______

(ii) The speed of sound in air is about 340 m/s. If you hear the thunder of a storm five seconds after you see the lightning, how far away is the storm raging? ______

6. What is the effect, if any, on the speed of sound in air if

(a) frequency of the sounding object is increased? ______

(b) the sounding object's loudness decreases? ______

(c) the temperature of air is raised? ______

7. The speed of sound in air is about 340 m/s. The audible range of frequency is 20 to 20,000 Hz. What is the range of wavelength of sound waves? ______

8. Describe with the aid of a diagram how dissipation of sound energy takes place from a vibrating tuning fork.

9. Distinguish between transverse and longitudinal waves and give one example of each.

10. How does a siren produce a note of constant pitch? Give a reason why the holes are evenly placed. If the disc rotates at 20 rev/s and the number of holes is 24, which note will be heard?

11. In which three ways can the pitch of a vibrating string be altered? On what factors does the loudness of a note produced by a vibrating string depend?

12. On which of the factors: mass of bob, amplitude of oscillation, length of string, does the time period of a pendulum depend? What would you do to adjust the time of a pendulum clock if it is running fast?

13. Fill in blanks.

(i) When objects____________sound is produced.

(ii) The loudness of the sound produced by an object depends on the____________ of vibration.

(iii) The speed of sound is____________(same/different) in different mediums.

(iv) In longitudinal wave motion energy is transmitted in the form of ______________ and ______________.

(v) Speed of sound = ______________/______________.

(vi) The lowest note produced by a vibrating object is called the ______________. The multiple frequencies of the ______________ are called ______________.

13

Magnets

Magnets are available in various shapes and sizes. At some time or the other you must have played with a magnet and marvelled at its property of attracting nails and pins. Do magnets only pull and never push? Do magnets attract any other objects besides nails, pins, etc ?

Experiment 1. Collect a number of small objects such as paper clip, brass screw, copper wire, iron nail, sewing needle, piece of wood, candle, glass rod, brass split pin, plastic scale, glass lens, steel spring, plastic knitting needle, post card etc. Test them with a magnet. List them under the headings: 'affected by a magnet', and 'not affected by a magnet'.

Our experiment shows that only objects made of iron and steel are pulled by a magnet. As a matter of fact, objects made of iron, cobalt and nickel only can be strongly attracted by a magnet. These materials are called ferromagnetic or simply **magnetic materials.** Scientists have now developed several other materials which are strongly magnetic; among these are alloys of iron, nickel and cobalt, ceramic materials like ferrites, and some special plastics. Materials which are not affected by a magnet, such as wood, glass, copper, etc. are called non-magnetic materials.

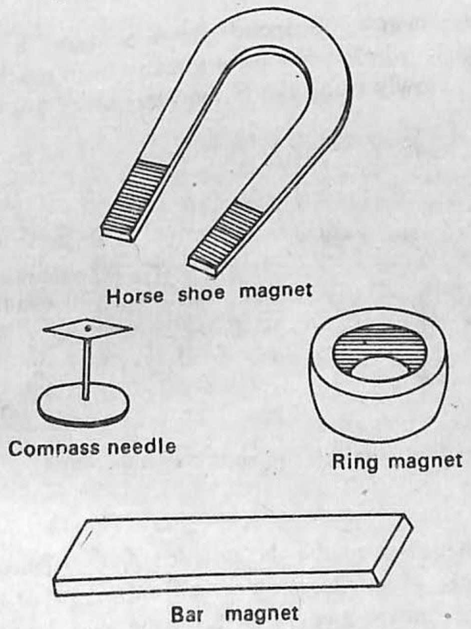

Horse shoe magnet
Compass needle
Ring magnet
Bar magnet

Fig. 13.1 Various types of magnets in use

13.1 Poles of a Magnet

Experiment 2. Take some iron dust and sprinkle it on a bar magnet. Notice how the dust clings to the magnet (Fig. 13.2). Now take an iron nail and touch it along the length of the bar magnet at several places. You would find that the iron dust makes a little bunch at each end of the magnet. The attraction on the nail is also greatest at the ends of the magnet. *The regions near the ends where the attraction i*

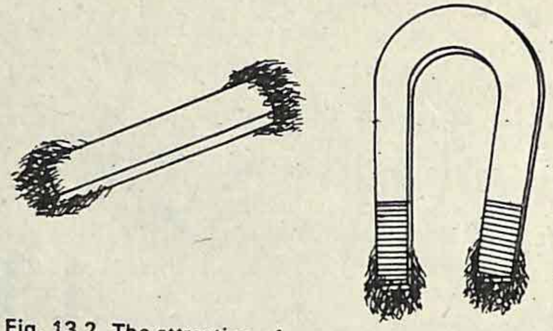


Fig. 13.2 The attraction of a magnet is greatest at the poles.

greatest are called the **poles** *of the magnet; a bar magnet has two poles.*

Repeat the experiment with a horse shoe magnet. You will find that it also has two poles at its ends.

13.2 Directional Property

Experiment 3. Suspend a bar magnet from a wooden stand (why wooden?) by using a paper hung from a thin thread (Fig. 13.3a). Make sure that there are no magnets or heavy iron masses nearby. After a few **oscillations** the magnet will come to rest. Disturb it from its position of rest and see what happens. Move the stand to some other position in the room and repeat the experiment.

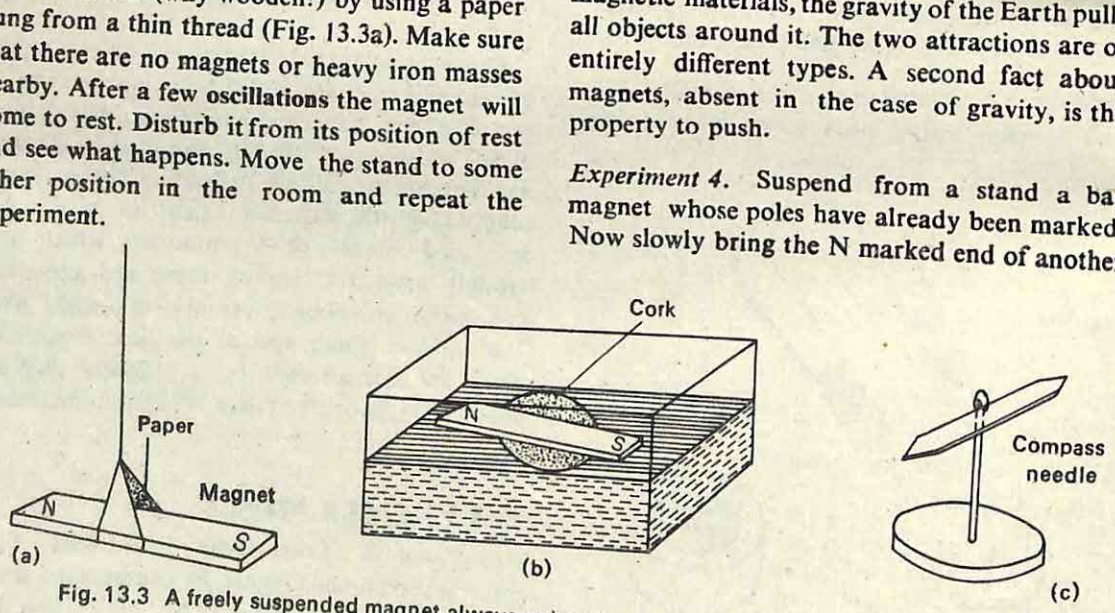


Fig. 13.3 A freely suspended magnet always points in approximately the north-south direction

You will notice that the magnet always comes to rest in the same direction; this direction is approximately along the geographic north-south. Mark the end pointing north as N; we call this a north seeking pole. Mark the other end as S; this is called a south-seeking pole.

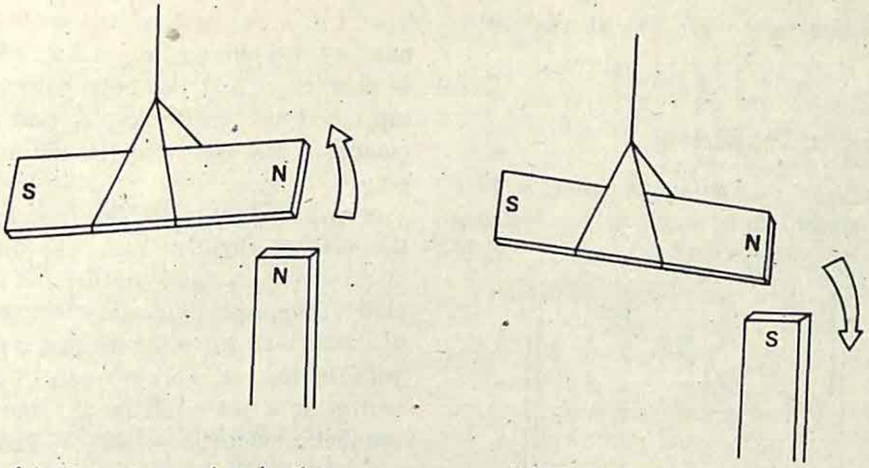
Another method of allowing a magnet to set itself freely in any direction is to float a magnet on a cork in a trough of water (Fig. 13.3b). Be sure that the magnet is perfectly still. The magnet will swing round and come to rest in approximately the north-south direction. It should be noted that the cork does not move either to the north or to the south but stays where it is in water.

A third way is to pivot a light magnetic needle on a sharp pivot. The needle always comes to rest in the north-south direction. This is called a **compass needle** (Fig. 13.3c).

13.3 Laws of Magnetism

One of the striking differences between the pulls of the Earth and a magnet is that while a magnet seems to attract only those objects made of magnetic materials, the gravity of the Earth pulls all objects around it. The two attractions are of entirely different types. A second fact about magnets, absent in the case of gravity, is the property to push.

Experiment 4. Suspend from a stand a bar magnet whose poles have already been marked. Now slowly bring the N marked end of another magnet close to the N pole of the suspended magnet (Fig. 13.4a). You will observe that the N-pole moves away. Let the suspended magnet come to rest and bring the S pole of the magnet



(a) Like poles repel each other

(b) Unlike poles attract each other

Fig. 13.4

in hand closer to the N pole of the first magnet and note the attraction (Fig. 13.4b). Similarly if you bring the S-pole of the magnet close to the S-pole of the suspended magnet you will find that they push each other. To this property of push we give a new name: **repulsion.** If the N-pole is, however, brought near the S-pole of the suspended magnet they attract each other. The conclusions from this experiment could be written as follows.

Like poles repel and unlike poles attract each other.

Test for Magnetism

A magnetic pole attracts an unmagnetised piece of iron as well as the opposite pole of another magnet. From this experiment alone, it is not possible to state definitely whether the other object is magnetised or not.

To test for magnetism, reverse the end of the magnet held in hand and bring it close to the object. If it is a magnet, a repulsion will be observed. Thus, *repulsion is a sure test for magnetism.*

Other methods to test magnetism are to suspend the object freely, or dip it in iron dust. If the bar is a magnet, it will come to rest in the north-south direction in the first case, and gather a large quantity of iron dust in the second case.

13.4 Making Magnets

You must have often wondered whether you can make a magnet yourself. Here is a simple method using a bar magnet.

Experiment 5. Take a magnetic object such as an iron nail or a paper pin. Stroke it with one end of the bar magnet. Begin stroking the object from one end and when you come to the opposite end, lift the magnet well away and bring it back to the first end of the object (Fig. 13.5). After doing this for some time, test the object to see if it has become a magnet. How will you find out which end is a north-seeking pole?

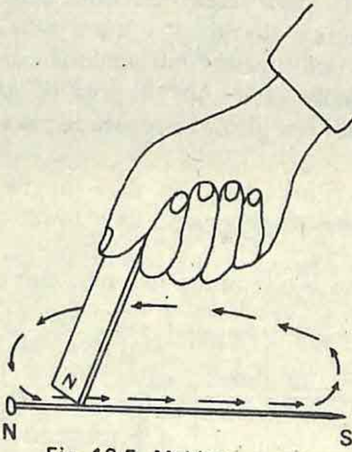


Fig. 13.5 Making a magnet

The magnetism of a magnet becomes weaker and finally disappears on rough handling, by either dropping it violently on the floor many times or by hammering it. Heating also destroys magnetism.

13.5 Magnetic Induction

A very interesting fact about magnets is their property to induce magnetism in magnetic materials which lie around in its field.

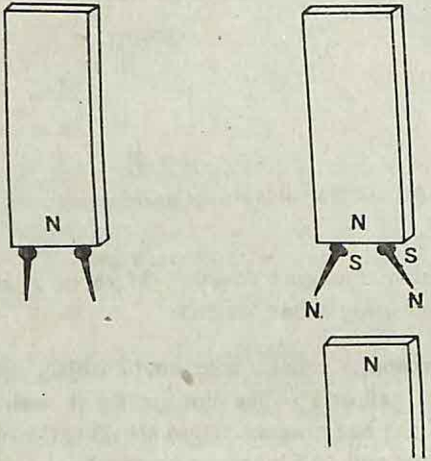


Fig. 13.6 Magnetic induction

Experiment 6. Support with a stand a bar magnet vertically with its N-pole downwards. Bring in contact with this pole two paper pins, separated by a small distance from each other (Fig. 13.6). You will notice that the two lower ends of the pins do not pull together but separate out. Now bring gradually closer the N-pole of another magnet under the pins; the separation is seen to increase.

The experiment suggests that the two pins have become magnets with their lower ends as N-poles.

Now remove one of the two pins and hang it from the lower end of the second pin. Try to hang a third pin, and so on, to build up a chain of pins (Fig. 13.7). See how many pins can be supported in this fashion. Repeat with another magnet. A stronger magnet will support more pins.

Now hold the top pin firmly and gently detach the magnet slightly. You will notice that the chain of pins remains together. It can be concluded that the magnetic effect can act from a distance, even when the magnet is not in contact with the top pin. This property of creating magnetism in a material due to the presence of another magnetic field is called **magnetic induction.**

If the magnet is gradually moved away, it is observed that the pins begin to fall away. However, one or two pins may remain hanging from the top pin. This shows that the pins have retained some magnetism. The experiment shows that the pins have become magnets themselves, but the effect is largely due to the presence of the permanent magnet. A small amount of magnetism is however retained even after the permanent magnet is removed.

Magnetic Induction in Iron and Steel

Experiment 7. Keep iron and steel bars of the same size over iron dust and touch the upper end of the two bars with one pole of a magnet. Iron and steel bars get magnetised and attract iron filings towards them (Fig. 13.8a). The iron bar attracts more dust than steel. Remove the magnet and note what happens. On removing the magnet, the iron piece drops almost all the iron dust clinging to it while the majority of dust keeps sticking to the steel bar. We conclude that steel gets magnetised less than iron under

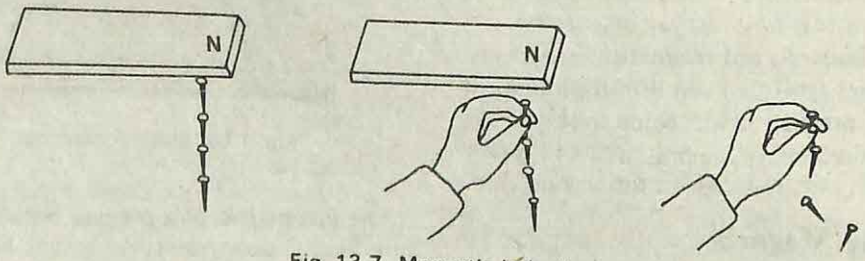


Fig. 13.7 Magnetic induction

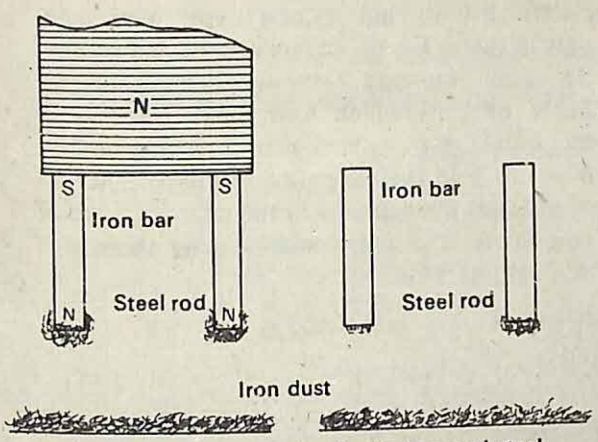


Fig. 13.8 Magnetic induction in iron and steel

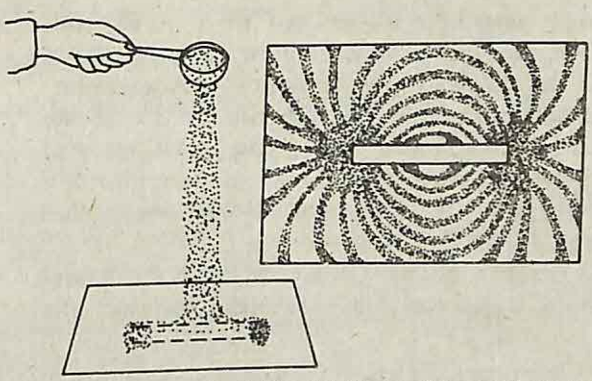


Fig. 13.9 Magnetic field and lines of force of a bar magnet

similar conditions but retains most of its magnetism when the magnetising source is removed. This is why iron is used in temporary magnets such as electromagnets, and steel is used in making permanent magnets.

13.6 Magnetic Fields

Bring a compass needle near a magnet, it gets deflected. Move the compass needle above, below and to the side of the magnet. It gets deflected showing thereby that magnetic influence extends all round the magnet. Take the magnetic needle further away. The magnetic influence becomes weaker and weaker until some distance away, it is not felt at all.

The region or the space around the magnet upto which its magnetic influence can be felt is called **magnetic field.** It is strongest near the magnet and decreases with distance.

Experiment 8. Place a cardboard over a magnet and sprinkle some iron dust on it evenly and not too thickly. Tap the side of the card with a pencil and note the pattern formed (Fig. 13.9).

The iron dust arranges itself along lines called **magnetic lines of force or field lines.** These are lines along which the magnetic force acts.

13.7 The Earth's Magnetism

That freely suspended or pivoted magnets point in definite directions all over the Earth suggests that the Earth has a magnetic field around it. The Earth behaves as if a huge bar magnet was embedded deep inside it with its poles approximately in the same direction as the geographical poles (Fig. 13.10). The magnetic field of the Earth resembles the field of a bar magnet and lies in a north-south direction; this is indeed fortunate as centuries of navigators will no doubt vouch for!

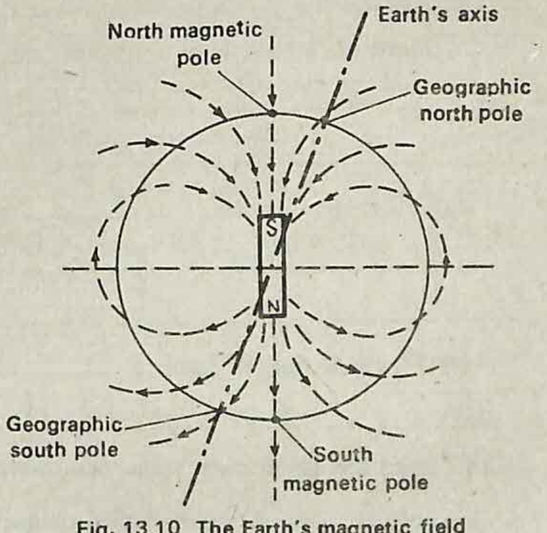


Fig. 13.10 The Earth's magnetic field

13.8 Uses of Magnets

A very old and ancient use of the magnet is in the magnetic compass. As you know a magnet when suspended aligns itself in a north-south direction. This is very useful in finding direction of travel and in spite of more sophisticated instruments, aircraft and ships still use the magnetic compass. Small pocket compasses are used by scouts and if you ever go on a hike or a trek, you would be advised to take one so that you do not lose your way.

Magnets are used in a large number of household appliances and industrial gadgets. The electric bell and motors of all types have magnets in them. Loudspeakers also have a magnetic core. You may have used some geometry boxes or belts which have small magnets in them. Refrigerators have magnetic strips on their doors to hold the door shut. An important use of magnets nowadays is in the memory cores of computers. This unit contains many thousands of small magnets.

EXERCISES

1. Explain

(i) Magnetic material ______________________________

____

(ii) North-seeking pole of a magnet ______________________________

____

____

(iii) Magnetic induction ______________________________

____

____

(iv) Magnetic lines of force ______________________________

____

2. (i) You are given two magnets of which one has poles labelled on it. How will you find out the poles of the unlabelled magnet without the aid of any other material? ______________

____

____

____

(ii) Give an experiment which you will perform using any other material you may need, to tell which one of the two is a stronger magnet. ______________________________

____

3. You are given three rods which appear exactly alike: one is a magnet, another is of iron and the third of a non-magnetic material. How will you find out which is which?

4. State how the magnetic property of iron differs from steel.

Which material would you use in

(a) an electric bell

(b) a permanent magnet

5. (i) What is meant by the term 'magnetic pole'?

(ii) How would you check that a particular end of a magnet is an N-pole?

6. Explain why two steel needles hanging from an S-pole of a strong magnet do not remain parallel.

7. (i) What is meant by the term magnetic field?

(ii) Draw a pattern of the magnetic field around a bar magnet.

8. Fill in the blanks.

(i) Three elements which are magnetic are ____________________, ____________________ and ____________________.

(ii) It is easier to magnetise ____________________ (iron/steel).

(iii) ____________________ is a sure test for magnetism.

(iv) ____________________(iron/steel) is used to make permanent magnets.

(v) Freely suspended magnets always point in approximately the ____________________ direction because of the magnetic field of the ____________________

14

Electrical Circuits

Fans, radios, heaters and irons are some of the electrical appliances which are in common use nowadays. From a handy torch to a giant ice factory, we have become increasingly dependent on the use of electricity for our daily activities. When you switch on an electric light in your home, do you ever wonder how the lamp is made to give light? What about the torch we often use? What part does a cell play in producing the bright beam of light in a torch?

A bus, motor car or a tractor have lamps inside to allow them to be driven at night. If you look under the 'bonnet' you will see lots of different coloured wires leading to the headlamps and other electrical gadgets in the vehicle such as the horn, windscreen wiper, and so on. To get an idea of how and why these gadgets work we begin by studying simple electrical circuits containing wires, cells and bulbs.

14.1 An Electric Circuit

Experiment 1. Take a bulb and connect it to a cell with two wires so that the bulb glows. The bulb connected by wires to a cell (Fig. 14.1) is a simple electric circuit. When the wires are connected correctly so that the bulb glows, it is said to be a **complete circuit**. You must have noticed that the two ends, called **terminals** of the cell, have to be connected to the two terminals of the bulb. If any one terminal is left unconnected, the bulb does not glow. This is why it is known as a circuit. Apparently, something electrical in nature comes out of the battery from one terminal and goes back to the battery through the other. Whenever there is a gap in a circuit, this electricity cannot get round it; the circuit is then said to be an **open circuit**. This suggests the purpose of a switch in a circuit.

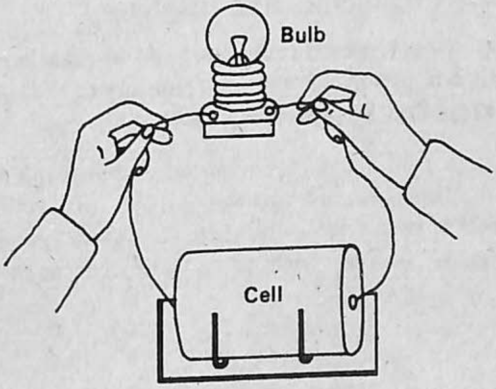


Fig. 14.1 A simple electric circuit

Experiment 2. Include a switch in a simple electric circuit containing one bulb and one cell (Fig. 14.2). Find out how the switch can be used to turn on and off the bulb. It is convenient and safer while working with household electrical

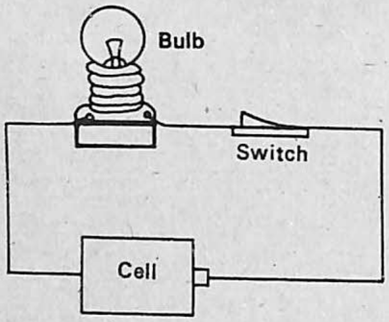


Fig. 14.2 A simple electric circuit with a switch

supply to hold the bulb in a **holder** or **socket.** Sockets come in various shapes and sizes; examine some of them and notice how their terminals are connected inside to the terminals of the bulb.

14.2 Conductors and Insulators

Are wires the only materials used to make a circuit complete? For example can any of the wires be replaced by a divider or a thread?

Experiment 3. Make a closed circuit using one lamp, one cell and two wires. Now remove one of the two wires and use a divider instead (Fig. 14.3). Test with other materials such as scissors, coin, paper pin, thread, key, glass rod, plastic scale, etc. You will notice that with the thread, glass rod and the plastic scale, the bulb does not glow, while it glows with the others.

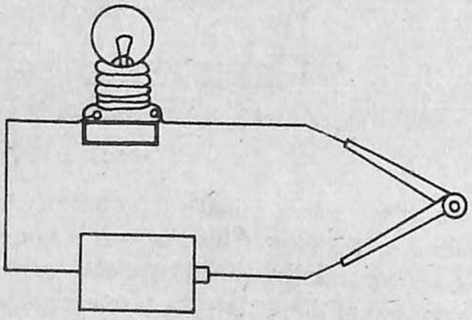


Fig. 14.3 To test for conductors and insulators

Materials which allow electricity to go through them are called **good conductors of electricity.** Metals are all good conductors of electricity. Those materials which act to create gaps in circuits by not allowing electricity to pass through them are called **insulators.** Most non-metals are insulators of electricity. When a switch is off, the gap is filled by air; air is, thus, an insulator.

14.3 Circuit Diagrams

Bulbs, wires, cells, switches, etc. all form elements of an electric circuit. We usually write certain symbols to show common circuit elements. Fig. 14.4 shows the circuit symbols of elements we have already talked about. Using these symbols, the simple circuit we have already constructed can be shown as in Fig. 14.5; this is called a **circuit diagram.** A complicated electric gadget contains many circuit elements.

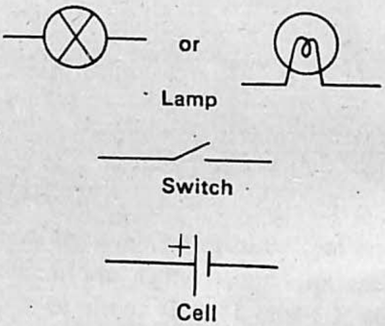


Fig. 14.4 Symbols for circuit elements

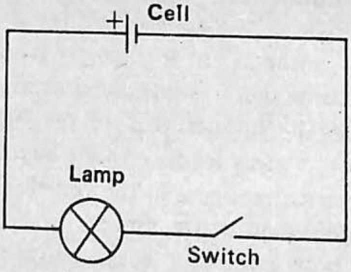


Fig. 14.5 Circuit diagram of a simple circuit

Experiment 4. Now take a cell and two lamps. Connect them as shown in Fig. 14.6. You will notice that the brightness of the bulbs is much less as compared to that in the earlier experiment with one lamp. Reverse the cell, or a lamp, and you will notice that there is no difference in the glow.

Now add one more cell in the circuit. You will

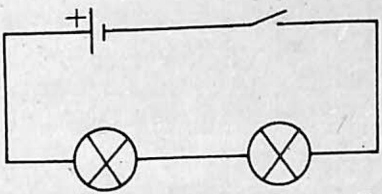


Fig. 14.6 A circuit consisting of one cell and two lamps

notice that the brightness of the lamps increases. Reverse one of the cells and you will observe that the lamps hardly show any glow. Many torches use three cells to give a powerful light. Can you draw a circuit diagram of the electrical arrangement which employs three cells, a lamp and a switch?

Series Circuit

When cells are connected so that the brass tip of one touches the base of another cell, they increase brightness of the lamps. For example, in the above experiment, the **two-cell and two-lamp** circuit which makes the lamps glow can be shown as in Fig. 14.7.

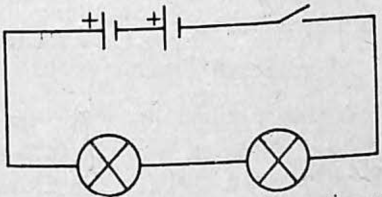


Fig. 14.7 A two-cell two-lamp series circuit

In this arrangement, the electricity which passes through one element passes through each of the other elements also. Such a circuit is called a **series circuit**. Unscrew any one of the bulbs and you will notice that the circuit is broken. If one of the bulbs gets fused then the other will not glow. In the three-cell torch, the cells are in series (Fig. 14.8) and help to increase brightness of the lamps.

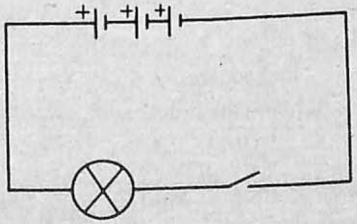


Fig. 14.8 A three-cell one-lamp circuit

In a series circuit if one bulb burns out, the entire circuit is affected. Also if we add one more bulb in the circuit the brightness of other bulbs decreases. Imagine how annoying it would be if the lights in your rooms dimmed because someone next door switches on lights in his room. This is one reason why electrical appliances in houses are connected in another way.

Parallel Circuit

Experiment 5. Take one cell and one bulb and connect them with wires so that the bulb lights up. Now take another lamp with wires attached to its terminals, and connect it to the cell so that this bulb also lights up without disturbing the first circuit. Notice the brightness of the two bulbs. The bulbs glow brighter in this case than when they were connected in series as in Experiment 4.

Draw a circuit diagram of the arrangement you have made; this should look like Fig. 14.9. Add one cell in series with the first and observe how the brightness increases.

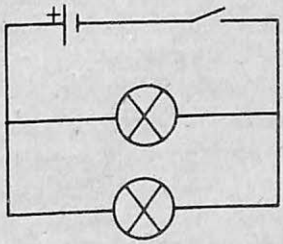


Fig. 14.9 A parallel circuit

The branching circuit you have made above is known as a **parallel circuit**. Unscrew one of the bulbs and you will see that the other continues to glow because its circuit still remains closed. If one of the two bulbs in a parallel circuit is blown off, it has no observable effect on the other. The second advantage of a parallel circuit is that one battery may be used to light more than one lamp.

Household Circuits

The circuits used in a household supply are parallel circuits. The circuits for each bulb, fan, radio, etc., branch out from the main terminal which is connected to the Power House; the Power House acts like a cell in the above experiments. In this way when any electrical gadget is switched on or off, the other appliances are not affected. Each appliance has an individual switch which is in series with it.

On the other hand, decoration lights for Diwali or Christmas are often connected in series. A number of small coloured bulbs are joined in series so that they are not very bright but give a pleasing appearance. Whatever electricity passes through one bulb, passes through all the other bulbs because there is no other alternate path. If one bulb is fused, it has to be replaced before all others start glowing again.

14.4 Current and Potential Difference

The fact that both terminals of a cell must be connected in a complete circuit suggests that something leaves the cell and a path must be provided for its return to the cell. It is rather like a circular car racing track. You can imagine a lot of cars going round and round the track. Suppose also that the cars on completion of each circuit refuel at a petrol station before they start off again.

Now if no fuel is given, or the tracks are blocked the racing would come to a halt. In a similar way one can imagine little electrical units going round the circuit. As they pass the lamps the lamps light up and show that the units are passing through. The electric units then get into the cell to receive energy to start round the circuit again with renewed energy. To these electrical units we give the name charge.

This description of what might be happening inside the circuit is a suggestion only but helps us to understand what may be happening inside the circuits. For example, if another parallel circuit with a bulb is connected to the first, it may work like another independent car track but the same petrol pump. The fuel would then get exhausted quicker, which is what actually happens to a cell.

Scientists always make suggestions of this kind to explain their observations and help their understanding. We could improve upon this suggestion as we learn about electrical circuits.

Potential Difference (P.D)

You are perhaps aware that a torch cell is marked 1.5 volt. A **volt** is a unit of **electrical pressure** or **potential difference (P.D.)** which is responsible for driving the charges round in a circuit. The positive terminal of the cell marked+(brass cap) is considered at a higher potential as compared to the negative terminal (zinc container); the charges are pushed from positive to the negative pole of the cell through the external circuit, which can be indicated by arrowheads in a circuit (Fig. 14.10).

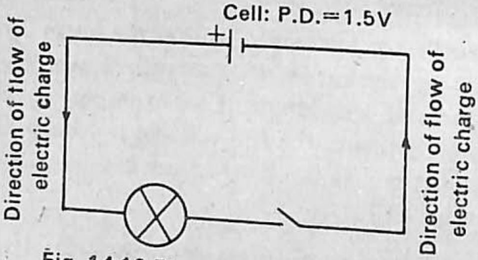

Cell: P.D.=1.5V
+
Direction of flow of electric charge
Direction of flow of electric charge

Fig. 14.10 Flow of charge in a circuit

If two cells are joined in series, they would create double pressure, and a lamp in series would glow brighter. Three cells in a torch would create a P.D. of 4.5 volts. However, if one of the three cells is reversed, its pressure will act in the opposite direction; hence, the effective P.D. would be 1.5 volt only (Fig. 14.11).

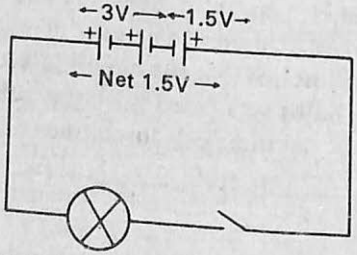


Fig. 14.11 A three-cell circuit with one cell reversed

Current

Potential difference is one of the two factors which governs the glow in lamps. The glow is an indication of the flow of charges, and the amount of energy they carry. *The rate at which the charges flow through an electric circuit is called* **current.** Current is measured in the unit **ampere (A).**

14.5 Resistors

We noticed earlier that when an additional bulb is added in series in a simple circuit, the glow in the bulbs becomes dimmer. What is it in a bulb, and what is its property, to bring about this change?

Experiment 6. Set up a circuit with three cells, a bulb, a switch and a 20 cm length of *nichrome* wire *AB* of 28 SWG thickness (Fig. 14.12). A slider *C* is used so that the contact on wire *AB* can be made as desired. Now switch on and observe the glow in lamp *L* as the slider is moved from the end *A* towards *B.*

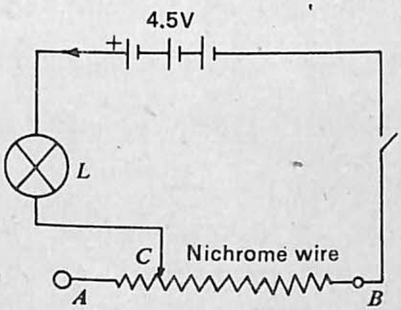


Fig. 14.12 A nichrome wire offers resistance to the flow of current

You will observe that the glow in the lamp increases as the length *CB* of the nichrome wire in the circuit becomes shorter.

Repeat the experiment using a thinner nichrome wire (36 SWG) in place of *AB.* You will observe that the glow in the lamp is much less. Thus, a shorter or a thicker wire increases the glow. A longer and thinner wire of nichrome reduces the glow in the lamp.

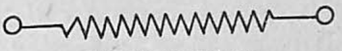
What actually happens is that the nichrome wire is being used to increase or reduce the flow of current through the circuit. Nichrome is, no doubt, a good conductor of electricity; however, it can be used to restrict the current when a length of the material is included in series in the circuit. *A conductor which alters or restricts the flow of electric current in a circuit is called a* **resistor.**

Resistance

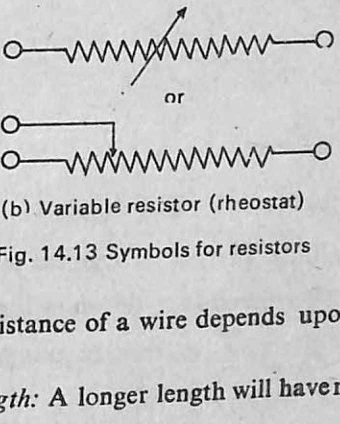
A thin and long wire shows this effect more prominently. It is said to have more **resistance.** Thus, resistance is the property of a resistor.

In the above circuit, the wire *AB* was used as a resistor. An additional bulb in a series circuit also does the same thing. A bulb is, in fact, a fixed resistor. It is the **filament** of a bulb which is responsible for its resistance. The thin wire is usually made of **tungsten** material.

The filament in a bulb is a fixed resistor. The wire *AB* was used as a *variable* resistor. Such variable resistors are called **rheostats.** For example, the *volume control* of sound in a TV or radio is a *rheostat.* The electrical symbol of this circuit element is shown in Fig. 14.13.



(a) Fixed resistor



(b) Variable resistor (rheostat)

Fig. 14.13 Symbols for resistors

The resistance of a wire depends upon three factors.

(a) *Length:* A longer length will have more resistance.

(b) *Thickness:* A thicker wire will have less resistance.

(c) *Material:* Nichrome and tungsten have greater resistance than copper and aluminium.

EXERCISES

1. Draw a simple circuit diagram with one cell, one lamp and one switch. Label all the parts; also show in the diagram, the direction of flow of current.

2. Draw circuit diagrams with one cell, one switch and two lamps (i) in series; and (ii) in parallel.

In which case will

(a) the lamps glow brighter? ______________________________

(b) the current through the cell be more? ______________________________

3. Two circuits are shown in Fig. 14.14. In which one will the glow in lamps be more?

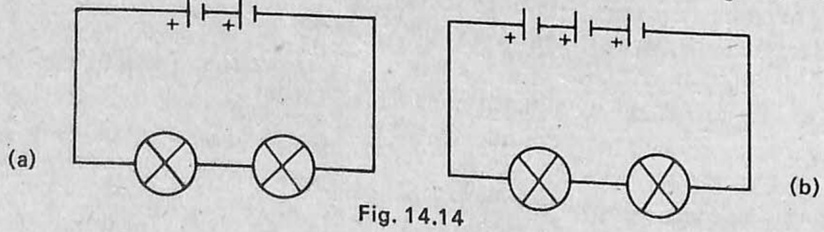


Fig. 14.14

4. Give two reasons why parallel connections of electrical appliances is desirable in domestic supply system. ______________________________

5. Plastic, rubber or varnish are some of the materials used to cover electrical wires. Electrical wires are usually made of copper or aluminium. State which of these are good conductors, and which are insulators, of electricity. Give your reasons.

6. (i) What are the units in which electric P.D. and current are measured?

(ii) What is the net P.D. across two cells in a torch?

(iii) What is the P.D. on which a TV normally operates?

7. (i) What does a resistor do?

(ii) Draw the electrical symbols of a fixed and a variable resistor.

8. Copper, aluminium, tungsten are all metals; they are all good conductors of electricity. Which of these materials would you choose for the filament of a bulb? Give your reason.

9. Fill in the blanks.

(i) A circuit consisting of a bulb, wires, a cell and a switch is properly connected. The switch is in the 'off' position. The circuit is ____________ (open/closed).

(ii) Air is a____________________(good/bad) conductor of electricity.

(iii) Current is the rate of flow of ____________________.

(iv) A variable resistance is called a ____________________.

(v) A long wire will have ____________________ (greater/lesser) resistance than a short wire of the same material. A thin wire will have____________________(greater/lesser) resistance than a thick wire of the same material.

15

Electric Cells and Energy

Electric cells produce electricity from a chemical reaction. All cells consist of two plates of different substances placed in a liquid. The plates which are called **electrodes** are made from a metal or carbon. The liquid, which is called an **electrolyte**, is a solution of an acid, a salt, or an alkali in water.

15.1 A Simple Cell

A simple cell consists of a copper plate and a zinc plate dipped into dilute sulphuric acid in a vessel (Fig. 15.1).

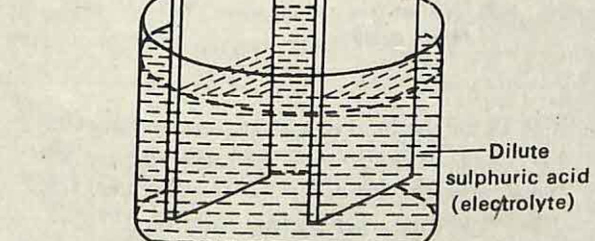


Fig. 15.1 A simple cell

The zinc dissolves and hydrogen is given off at the copper plate. This chemical action builds up positive charges on the copper electrode. Thus a pressure difference (P.D.) develops between copper and zinc, the copper being at 1.1 volt higher potential.

When the two plates are connected by wires to a torch lamp, the *positive charges flow from copper to zinc in the external circuit*, and the lamp is seen to glow.

A simple cell thus converts chemical energy into electrical energy. When current flows, this electrical energy is converted into light and heat energy at the bulb. The sequence of energy change can be written as follows:

Chemical energy (stored in the chemical) → Electrical energy (in the cell)
→ Light & heat energy (in the lamp)

15.2 The Dry Cell

The dry cell or the torch cell is used in torches, portable transistor receivers and many toys. Its parts are shown in Fig. 15.2.

The carbon rod with a brass cap serves as a positive electrode. It is surrounded by a moist mixture of finely divided manganese dioxide and

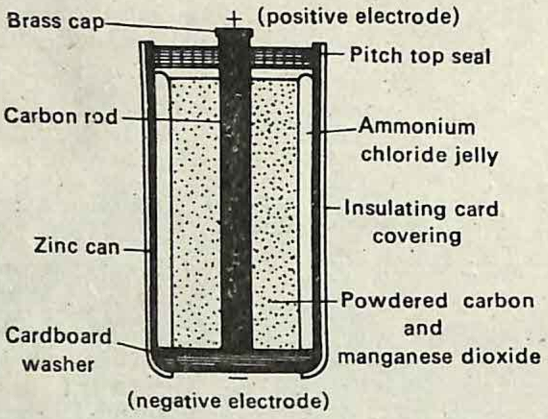


Fig. 15.2 A dry cell

powdered carbon. The zinc container serves as the negative electrode. The electrolyte is ammonium chloride in the form of a jelly-like paste. A piece of cardboard placed at the bottom of the zinc container insulates the carbon rod from the zinc case. A layer of pitch seals the top of the cell and prevents the chemicals from drying out. The cell itself is dry from outside but its contents are kept moist or otherwise it will not work.

The cell develops a P.D. of 1.5 volts across the two terminals.

15.3 Secondary Cells

The two cells studied earlier are called **primary cells**; when they run down by use, the cells have to be thrown away. In other words, when the available energy due to chemical reaction in them is utilised, the chemicals are thrown away. We then say that the cell is **discharged.**

There is another group of cells in which energy is first stored in the form of chemical energy by passing electric current through them from an external source. In this process some chemical reactions take place. This process is called **charging**. The stored chemical energy in the charged cell can be obtained as electrical energy by reverse chemical reactions. Such cells are called **secondary cells, storage cells or accumulators.**

Lead Accumulators

Lead accumulators are the commonest type of secondary cells. In its simplest form a lead accumulator consists of two heavy grid shaped lead electrodes suspended in dilute sulphuric acid contained in a glass or perspex container.

When the cell is charged, the positive electrode gets coated with lead dioxide and the negative with spongy lead; the specific gravity of the acid rises from 1.15 to 1.25 and the P.D. becomes 2.1 V. On discharging, both the electrodes are coated with lead sulphate and the specific gravity of the acid falls. The cell should be recharged before the P.D. falls below 1.8 V, otherwise it may get permanently damaged.

Whether a cell is fully charged or not is checked by measuring the relative density of the acid with a special hydrometer shown in Fig. 15.3.

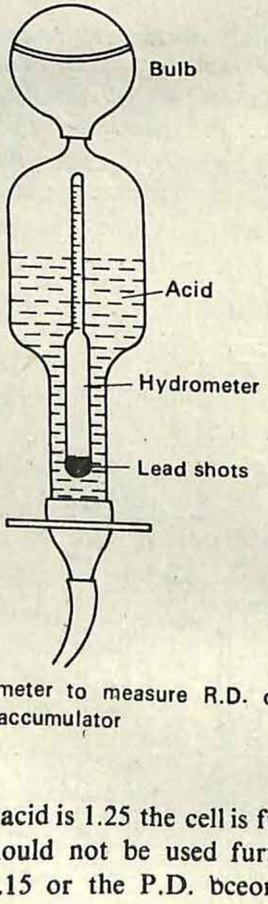


Fig. 15.3 Hydrometer to measure R.D. of acid in a lead accumulator

If R.D. of the acid is 1.25 the cell is fully charged. The cell should not be used further when R.D. falls to 1.15 or the P.D. bceomes 1.8 V, otherwise it may get permanently damaged.

Care and Maintenance

1. The level of the acid in the cell should be

inspected regularly and distilled water should be added from time to time to make up for any loss due to evaporation.

2. Acid should never be added except in rare cases when spillage has occurred.
3. Cells should be charged regularly using the manufacturer's recommended current rating and should never be left for any length of time in a discharged condition.
4. The cell should never be charged too rapidly by sending a large current. This would cause brisk evolution of gases and may blow off active material from the plates.
5. Over discharging and 'shorting', i.e. connecting a good conductor directly across the terminals, must be avoided. The very heavy current will remove the active material from the plates.

Advantages and Disadvantages

The main advantage of an accumulator is that when discharged, it can be recharged a number of times. Even when its initial cost is very high it is more economical in the long run than dry cells. Another advantage is that a large current for a long duration can be obtained from an accumulator because its internal resistance is low.

Its main disadvantage is that it is heavy and there is a danger of the corrosive acid spilling over. Also it requires great care for proper maintenance.

The **current carrying capacity** of an accumulator is measured in ampere-hours (AH). If a battery is rated as 80AH, this means that it will give a current of 8A for 10 hours and a 2A current for 40 hours. This, however, is an approximation since the capacity is more for smaller currents than when it is discharged rapidly using large currents.

15.4 Electrical Energy

The electrical energy drawn from a cell or by an electrical appliance in household use depends upon three factors.

(a) *P.D.* If the potential difference is greater, the energy supplied would be more. For example, since the P.D. developed by a lead accumulator (2.0 volts average) is considerably more than that of a dry cell (1.5 volts), the lead accumulator can supply more energy, other factors remaining unchanged.

On the other hand, the energy consumed by household electrical appliances varies due to other factors because all of them work on the same P.D. (approximately 220 volts).

(b) *Current.* If the current drawn is more (i.e. the rate at which the energy-carrying charges are going round the circuit is greater), the energy drawn is more.

When the P.D. is the same, as for all domestic electrical appliances working on 220 V, the current drawn would vary depending upon the resistance of the appliance. A bulb of less resistance will draw more current, hence its energy consumption will be greater.

(c) *Time.* If an electrical appliance is operated for a longer duration, the energy consumption is more.

Energy Calculation

For calculation of energy consumption, the following mathematical relationship is useful.

$$\text{Energy} = \text{P.D.} \times \text{Current} \times \text{Time}$$

$$\underset{\text{(joule)}}{E} = \underset{\text{(volt)}}{V} \times \underset{\text{(ampere)}}{I} \times \underset{\text{(second)}}{t}$$

EXAMPLE 1. If a car battery of 12 volt P.D. gives a 25 ampere current for 3 seconds while starting a car, what is the electrical energy used up?

Solution. Energy used up,

$$E = 12 \text{ volts} \times 25 \text{ amperes} \times 3 \text{ seconds}$$
$$= 900 \text{ joules}$$

Answer

In practice, household appliances require a very large amount of energy. Hence, multiple units of energy and time are used as follows.

Energy in watt-hour (Wh)
= P.D. (volts) × current (amperes) × time (hours)

EXAMPLE 2. If a bulb operates for 20 hours on

225 volts and draws a current of 0.4 ampere, what is the electrical energy it consumes? If the rate of payment for electrical energy is 50 paise per unit (1 unit = 1 kWh) what would be the cost of electrical energy consumed?

Solution. Energy used up

$$= 225 \text{ volts} \times 0.4 \text{ ampere} \times 20 \text{ hours}$$
$$= 1800 \text{ watt-hour}$$
$$= 1.8 \text{ kilowatt-hour (kWh)}$$

It the rate of payment for electrical energy is 50 paise per unit:

The cost of operation = 1.8 × 50 paise
= 90 paise *Answer*

Power

Power is defined as the rate of doing work; it is equal to the consumption of energy in a unit time.

$$\text{Power}(P) = \frac{\text{Work done or energy consumed } (E)}{\text{Time of operation } (t)}$$

Thus $P = \dfrac{V \times I \times t}{t} = V \times I$

or Power (watts) = P.D. (volts) × Current (amperes)

EXAMPLE 3. An electric heater operates on 250 volts and draws a current of 8 amperes. What is its power consumption?

Solution. Its power consumption

$$P = 250 \times 8 = 2000 \text{ watts}$$
$$= 2 \text{ kW}$$ *Answer*

EXAMPLE 4. Two head lamps, each marked 48 W were left switched on for half an hour. The car battery had a P.D. of 12 volts. What was the (a) energy wasted, (b) current drawn from battery?

Solution. (a) Energy consumption

$$= \text{power} \times \text{time}$$
$$= (48 + 48) \times \tfrac{1}{2} \text{ Wh} = 48 \text{ Wh}$$ *Answer*

It should be noted that the two bulbs are connected in parallel and, hence, draw energy independently.

(b) Current drawn by each bulb

$$= \frac{\text{Power}}{\text{P.D.}} = \frac{48}{12} = 4 \text{ amperes}$$

Since each bulb draws 4 amperes of current independent of the other, being connected in parallel, the total current drawn from battery = 4 + 4 = 8 amperes *Answer*

EXAMPLE 5. A battery is fully charged. It is rated 90 AH. When a bulb of 12 V, 24 W rating is connected across it what is (a) the current drawn (b) the energy drawn in 50 minutes? (c) How long can the battery last?

(a) The current through the bulb when connected to the battery

$$= \frac{\text{Power}}{\text{P.D.}} = \frac{24 \text{ W}}{12 \text{ V}} = 2 \text{ amperes}$$ *Answer*

(b) Energy = Power × Time

$$= 24 \text{ W} \times 50 \times 60 \text{ seconds}$$
$$= 72{,}000 \text{ joules} = 72 \text{ kJ}$$ *Answer*

(c) The battery has a total charge of 90 ampere hour. Hence, the time it can last at 2 amperes discharge rate

$$= \frac{90 \text{ AH}}{2 \text{ A}} = 45 \text{ hours}$$ *Answer*

15.5 The Fuse

An appliance is designed to take a certain current. If per chance due to 'short circuiting' or some other reason the current becomes very high, it is likely to damage the appliance and the electric wiring may catch fire. To avoid this risk a safety device called *fuse* is used in series with the circuit.

Fuse is a short piece of wire of a low melting point material which is connected in series and melts when the current rises above the safe limit. This breaks the circuit and switches off the current.

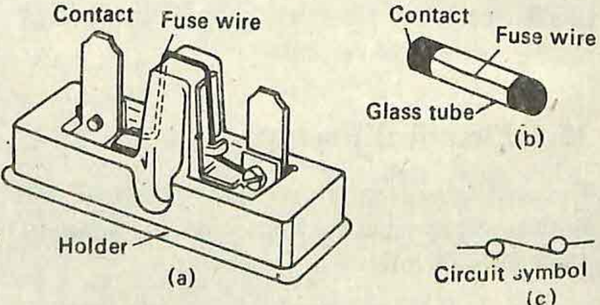


Fig. 15.4 Fuse wire and its circuit symbol

Fig. 15.4a shows the type of fuse that is used in the main fuse box of the house. A melted piece of fuse wire can be replaced by fastening a new piece between the contacts. Fig. 15.4b shows a cartridge-type fuse. When the wire melts in this type of fuse, the whole cartridge has to be replaced. The circuit symbol of the fuse is as shown in Fig. 15.4c.

Fuse wires are of different current-carrying capacities. An electric kettle of 2 kW will take $2000/220 \simeq 9$ A current. A thick fuse wire rated 15 A must be used. For electric lighting, suppose 8 lamps of 60 W each are used in a house. They will take a current of $60 \times 8/220 \approx 2.2$ A. A thin fuse wire of 5 A should be used.

EXERCISES

1. (i) Draw a labelled diagram of a simple cell. Name the electrodes and the electrolyte and show the direction of current when the cell is connected to a bulb.

(ii) What P.D. does this cell develop? ____

____

(iii) What is the sequence of energy change taking place when the bulb glows? ____

____

____

2. (i) Draw a labelled diagram of a dry cell.

(ii) What advantage does this cell have over the simple cell? ____

____

____

____

____

(iii) What P.D. does this cell develop? ____

3. (i) What are secondary cells? Given one example. ____

____

____

(ii) What P D. does it develop?

4. (i) What are the electrodes and the electrolyte of a lead accumulator?

(ii) What is the range of its P.D. normally maintained?

(iii) How is this tested?

5. State the advantages of lead accumulator over other cells.

6. Give the equation which relates the energy discharge of a cell to other factors. Give proper units.

7. A bulb is rated 100 W, 240 V. When in normal operation for 5 hours

(i) how much current will it draw?

(ii) what will be the energy utilised by it?

8. An electric appliance draws 5 ampere current when operated on 230 volts. The cost of electrical energy is 60 paise per unit (1 kWh) and the appliance is operated for 15 hours. Find

(i) the power rating of the appliance.

(ii) the cost for total energy utilised.

9. Why is a fuse wire used in a circuit?

10. Indicate whether the following statements are true or false.

(i) The contents of a dry cell are kept moist or else the cell will not work.

(ii) Primary cells can be 'charged' by an external current.

(iii) A lead accumulator is likely to be permanently damaged if left in a discharged condition for a long time.

(iv) To charge a lead accumulator it is better to use a large current for a short time rather than a small current for a long time.

(v) A lead accumulator is as easy to maintain as a dry cell.

(vi) A lead accumulator rated as 40 AH can supply 1 ampere current for 40 hours.

(vii) Electrical energy = P.D. × Current/Time

(viii) Power = P.D. × Current

(ix) It is proper to use a 5A fuse wire for a heater of 1.5 kW.

(x) The R.D. of acid in a lead accumulator is 1.25 for a fully charged cell.

16

Effects of Electric Current

Some materials have a high resistance to the passage of electricity through them. Others have a low resistance. The resistance of any object is fixed but it is difficult to measure directly. The resistance of an object is found by measuring the current flowing through it when a known potential difference is applied.

An object has a resistance of 1 ohm (written as 1 Ω) if a potential difference of 1 volt causes a current of 1 ampere to flow.

16.1 Ohm's Law

This law concerns what happens when the potential difference across a resistor increases, as in Fig. 16.1.

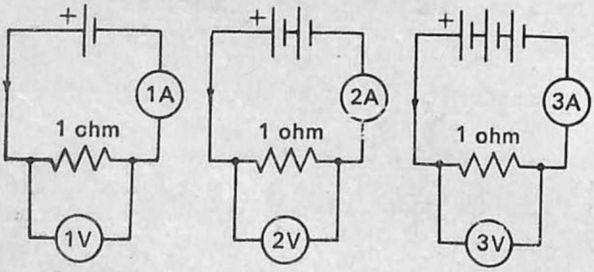


Fig. 16.1 Current is proportional to potential difference

It is found that a potential difference of:

1V drives 1A through the 1 ohm resistor,
2V drives 2A through the 1 ohm resistor.
3V drives 3A through the 1 ohm resistor.

From this it can be seen that:

$$\text{Resistance (ohms)} = \frac{\text{Potential difference (volts)}}{\text{Current (amperes)}}$$

The results show that the current increases in step with the potential difference. In other words, the current is *proportional* to the potential difference. This is known as **Ohm's Law.** It can be stated as follows.

Provided the temperature remains constant, the current flowing through a resistor is proportional to the potential difference across its ends.

16.2 The Heating Effect

Electric energy is converted into heat energy whenever an electric current flows through a resistor. The heating depends upon the current. the P.D. and duration of flow.

The heating effect due to an electric current is utilized in a large number of electrical appliances such as electric room heaters, electric bulbs, kettles, immersion heaters, toasters, cookers and electric irons. All heating appliances consist primarily of two parts.

(i) A resistor called **filament** which is a coiled length of nichrome wire of suitable length.

Nichrome is an alloy of 60% nickle and 40% chromium; it resists oxidation even when red hot. Its temperature can rise upto 900°C.

(ii) The insulating base of fire-clay, mica, silica or asbestos in which the filament is embedded. As the flow of current through the human body is highly dangerous and may even cause death, proper care is taken not only to insulate it from the filament but also to earth it so that if per chance leakage occurs, charge flows to the earth instead of the human body. The above materials are not only insulating but are also able to withstand the high temperature of the filament.

The Electric Lamp

The electric lamp is the simplest example of a converter of electric energy into heat and light energy. The bulb (which works on the mains supply) has a short and thin filament which is so coiled that the surface exposed is very small. Moreover, the filament is enclosed in a glass bulb which contains very little gas. Thus, heat losses due to convection and radiation are minimised considerably. The temperature of the filament is therefore very high, in the region of 2500 to 2700°C. This enables it to dissipate energy largely in the form of light. To withstand this high temperature, the filament is made of **tungsten**, whose melting point is about 3500°C. The near vacuum inside the bulb does not allow oxidation of the filament to take place, thus enabling its temperature to be raised very high. Usually an inert gas like nitrogen or argon is introduced in the bulb at low pressure.

Electric Iron

The electric iron works in the same way as the electric heater. However the element is wound onto a strip of mica and is insulated from top and bottom by two other sheets of mica (Fig. 16.2). An asbestos sheet is placed on the top to act as heat insulator. On it a heavy metal sheet is placed to press it down. The whole arrangement is clamped tightly onto a thick polished iron sole plate.

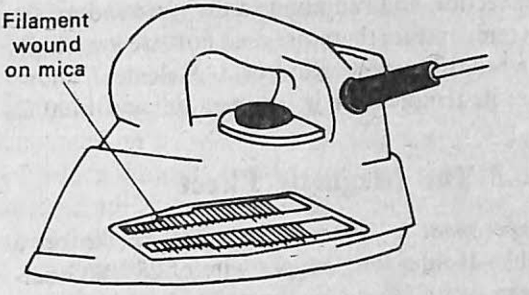


Fig. 16.2 The electric iron

A bimetallic strip is fitted onto the iron to act as a thermostat for keeping the temperature constant by automatically switching 'on' and 'off' the current. The required temperature can be obtained by adjusting the distance between the contacts with the help of a knob.

The Electric Heater

We have seen that three ways in which the resistance of a conductor can be altered are: change of length, thickness and material. The filament of a bulb and the element of a heater differ in all these three respects.

If the two have the same resistance and the electric current passing through them is also the same, both will convert electrical energy to the same extent; however, the construction being different, one will give more light while the other will give more heat radiation.

The heater element is made of nichrome; the wire is thick, long and well exposed to air (Fig. 16.3). When electrical energy is converted to heat energy, the greater surface, and contact with air, enables it to dissipate heat quickly by

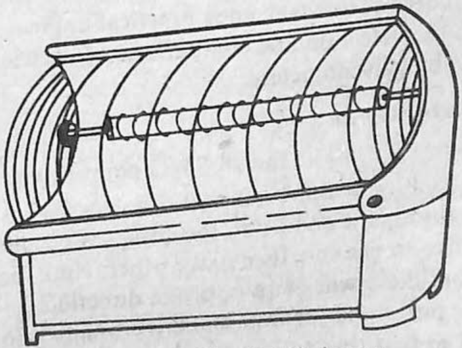


Fig. 16.3 The electric heater

convection and radiation to the surrounding air. Its temperature therefore does not rise very high; the reddish yellow glow of the element shows that its temperature is between 800 and 1400°C

16.3 The Magnetic Effect

Experiment 1. Place a compass needle on a table. Hold a long copper wire of 28 SWG between your hands in the north-south direction on top of the needle, and connect its two ends to a cell (Fig. 16.4). You will notice a deflection of the needle. Now hold the wire below the needle. Again there is deflection but in the opposite direction.

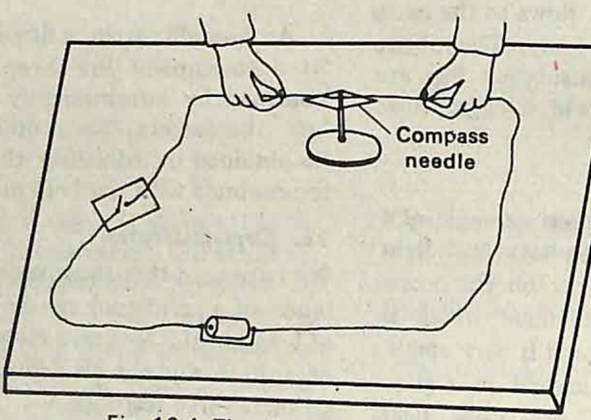


Fig. 16.4 The magnetic effect of a current

This shows that when a current flows in a wire, it creates a magnetic field around it which causes the magnetic compass to be deflected. This is known as the **magnetic effect** of an electric current. The deflection increases with increase of current; this fact finds practical applications in the detection and comparison of electric currents by galvanometers.

The Electromagnet

Experiment 2. Make the 28 SWG copper wire into a coil by wrapping it round a pencil. Pass current through it and bring the compass needle near it, first to one end, then to the other. Note the deflection; these will be in opposite directions.

Now put three or four small iron nails into the coil so that the coil is wrapped round the nails. Bring the compass needle near it and again note the deflections. You will observe that the deflections are now more. Bring other nails near it; these will be attracted to the nails inside, and may even get attached to them. Increase the current by including more cells in the circuit; the magnetic effect will also be enhanced.

Such a long coil which carries electric current and produces a magnetic effect is called a **solenoid**. When nails are inserted through it, it behaves as an electromagnet. The electromagnet attracts iron and other magnetic pieces just like a bar magnet. A simple rule to remember which end becomes the N-pole and which becomes the S-pole,is to view the end faces from the sides. If the current around the core is clockwise, the face is an S-pole. If the current is anticlockwise the face is an N-pole (Fig. 16.5).

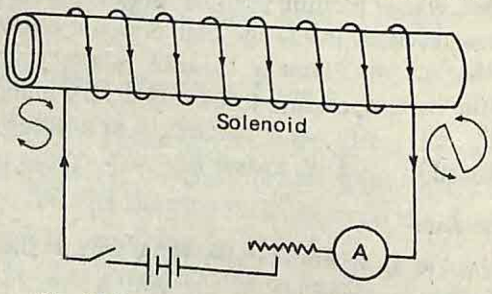


Fig. 16.5 A solenoid with N and S poles

Experiment 3. Now pick some heavy objects with the electromagnet, e.g. a steel ball. Switch off the current. What do you notice? Bring some pins close to the coil; you will see that the pins may continue to be attracted even when no current flows through the coil. Thus, there may be some residual magnetism left in the iron core of the electromagnet, but its strength is much less now than when the current was passing.

As you know, soft iron loses much of its magnetism very quickly; it is therefore used in electromagnets when we want the magnetic effect to be temporary for the duration of the flow of current. However, permanent magnets from steel are also made in a similar way by passage of high current through coils wrapped round them.

The Electric Bell

Electromagnets are used in many devices such as relays, automatic cut-outs, etc. The electric bell is a simple and common practical application. It uses an elctromagnet which switches on and off automatically, causing a hammer to strike a gong repeatedly (Fig. 16.6).

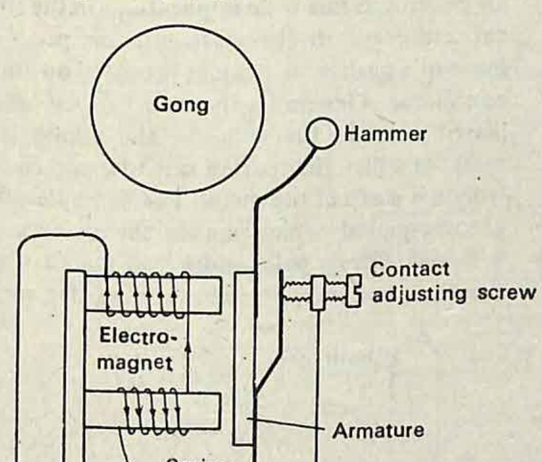


Fig. 16.6 The electric bell

The bell consists of an electromagnet, one end of whose winding is connected to the terminal screw T_1 and the other to the armature. The armature consists of a piece of soft iron bar mounted on a springy bit of steel the other end of which presses against the silver tip of the contact adjusting screw. The screw is joined to the other terminal T_2.

On pressing the push button the circuit is completed and current flows through the electromagnet which attracts the armature towards it. This makes the hammer strike the gong and separates the contacts. This switches off the current through the electromagnet which consequently loses its magnetism. The armature and the hammer now spring back closing the contacts again. This allows the current to flow again such that the whole cycle repeats again and again until the current is switched off.

The electric buzzer works in exactly the same way except that there is no gong. The sound is produced by the vibration of the armature itself.

16.4 The Chemical Effect

So far we have come across many examples of conductors and insulators of electricity; these were all solids. Liquids also conduct electricity.

Experiment 4. Take several liquids in separate beakers. Fix two pencil 'leads' or carbon rods to three cells and a lamp and dip the two carbon rods into the liquids one by one (Fig. 16.7). The

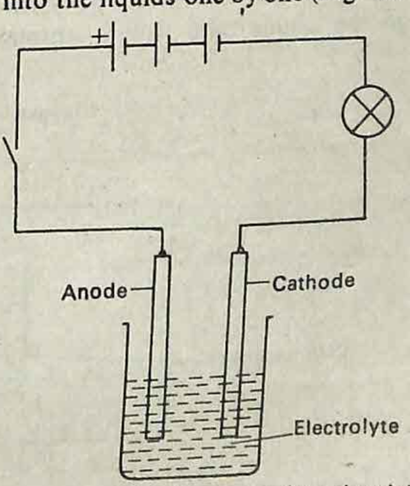


Fig. 16.7 Some liquids can conduct electricity

carbon rods can be easily obtained from cells that have been used up in previous experiments. If the liquid conducts, the lamp will glow. Make a table and record your observations for the different liquids.

You will discover that pure water and kerosene are insulators while dilute sulphuric acid, mercury and copper sulphate solution in water are some of the liquids which conduct electricity.

Now repeat the experiment more carefully with a solution of copper sulphate. Pass a current for about 5 minutes. Remove the rods.

You will notice that one rod appears pinkish. If you test the rod on a Bunsen flame, it glows with a typical green flame of copper. Where has the copper come from? During the passage of electric current, some chemical change takes place and copper from the solution is released which gets deposited on one of the rods.

Electrolysis

Liquids which conduct electricity accompanied by a chemical change are known as **electrolytes**. For example, copper sulphate solution is an electrolyte while mercury is a non-electrolyte. The conductors that dip into the liquid to make electrical connection are known as **electrodes**. In the above experiment, the two carbon rods were used as the electrodes. The electrode connected to the positive terminal of the cell is known as **anode** and that connected to the negative terminal of the cell is called **cathode**. Electric current enters the liquid through the anode and leaves through the cathode. Copper was deposited on the cathode in the above experiment.

Experiment 5. Replace the carbon electrodes with nichrome, or preferably platinum wires. Bend the platinum wires into a hook so that they rest on the rim of a beaker filled with distilled water, with only the platinum electrodes dipped in water. Connect the circuit and you will notice that the lamp does not glow.

Now carefully add a few drops of sulphuric acid to the water; the liquid begins to conduct. You will observe gas bubbles forming around both the electrodes. Collect the gas in test tubes; for this, the test tubes are first filled with the electrolyte, and then inverted and held over the electrodes (Fig. 16.8). Test the gas with a glowing splinter. It will be found that the gas collected at the cathode is hydrogen while that at the anode is oxygen. Thus water can be easily separated into its components by **electrolysis.**

Applications to Chemical Industry

Electrical separation by passage of current into an electrolyte has wide applications in the chemical industry. In the **electroplating** process, a layer of a particular element is coated on another conductor. Generally, the object to be electroplated is made the cathode; the anode is the metal of which the coating is made, and the electrolyte is a salt of the metal. For example, iron is chrome-plated which makes the surface rust-resistant. Silver, gold and nickel plated objects acquire a better appearance and harder surface.

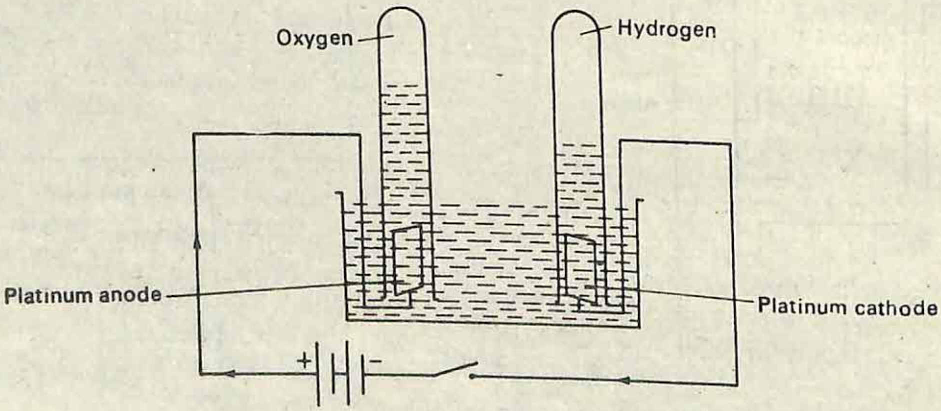


Fig. 16.8 Electrolysis of acidified water

Electrotyping is a process by which the type for printing materials are made; this depends upon the principle of electroplating.

The electroplating process is also used to refine metals; a pure coating of a metal on the cathode is obtained when the anode is impure. Gold, silver, zinc and tin are obtained in refined form in this way. Extraction of aluminium, sodium, etc. also depends upon the electrical method of separation.

EXERCISES

1. (i) What is the relation between current through a resistor, its resistance and the applied P.D.? __________

   (ii) What is the law governing this relation called? __________

2. A 2 volt cell is connected across a 4 ohm resistor.

   (i) What current will flow through the resistor? __________

   (ii) How much power will be drawn by the resistor during the energy conversion? __________

3. State the material of which each of the following wires are made? Give a reason for the use of this material.

   (i) Fuse wire __________

   (ii) Element of an electric heater __________

   (iii) Filament of a bulb __________

   (iv) Connecting wire __________

4. Draw a labelled diagram of an electric bulb.

   Why is the 'coiled-coil' type of filament used?

   ____

5. Fig. 16.9 shows an incomplete diagram of an electric buzzer. Complete the diagram and label it.

6. What factors affect the strength of the magnetic field of a coil carrying electric current? ________________

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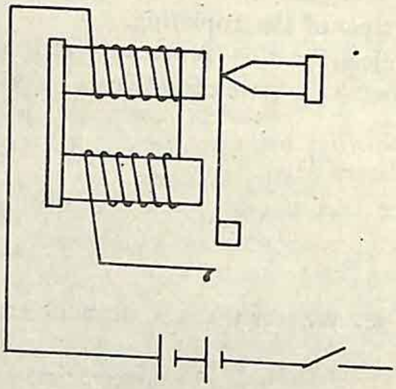

Fig. 16.9

7. Classify the following examples under the headings magnetic, heating and chemical effect of electric current:

   (i) electricity produces light. ________________

   (ii) electricity rings an electric bell. ________________

   (iii) electricity charges a car battery. ________________

   (iv) electricity gives a severe shock. ________________

   (v) electricity is used to purify copper. ________________

   (vi) electricity blows off a fuse. ________________

8. Fill in the blanks.

   (i) If a P.D. of 2 V drives a current of 1 A through a resistor, 3V will drive a current of ________________.

   (ii) A ________________ is a coil carrying electric current and producing a magnetic effect.

   (iii) The core of the electromagnet in an electric bell is made out of ________________ (soft iron / steel/brass).

   (iv) A liquid which conducts electricity accompanied by a chemical change is known as an ________________.

   (v) Mercury ________________ (is/is not) an electrolyte.

   (vi) The electrode connected to the positive terminal of the cell is the ________________. Electric current ________________ (enters/leaves) the liquid through this electrode.

   (vii) The surface of iron is made rust-resistant by coating it with ________________ by a process called ________________

Answers to Numerical Problems

Chapter 2

6. (i) 250 cm^2 (ii) 60 cm^2

Chapter 3

2. (1) Volume = 40 cm^3 (2) Density = 21 g/cm^3
   (3) Mass = 222.5 g
3. 7.5 kg
5. (a) 25 cm^3 (b) 0.8

Chapter 5

7. 68 cm
8. 80 gf/cm^2

Chapter 8

3. (ii) (a) 117.8°C (6) 77°F

Chapter 9

3. (ii) 0.5 cm

Chapter 11

10. (ii) 3.33 dioptres (iii) -25 cm; diverging lens

Chapter 15

7. (i) 0.42 A (ii) 0.5 kWh
8. (i) 1150 W (ii) Rs. 10.35

Chapter 16

2. (i) 0.5 A (ii) 1 W
8. (i) 1.5 A

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